Glacier Bay National Park
Science Advisory Board: Final Report

Research and Monitoring Needs Relevant to Decisions Regarding Increasing Seasonal Use Days for Cruise Ships in Glacier Bay

Appendices

Prepared by the

Glacier Bay Vessel Management
Science Advisory Board

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Appendices

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Appendix A:

Categories of Glacier Bay Visitors and Visitor Trends

This framework adopts the conventions used in the FEIS for describing visitor categories: cruise ships, tour vessels, charter vessels, private vessels, and backcountry visitors (NPS 2003: 2-2 – 2-6).

Cruise ships. A cruise ship is defined as any motor vessel at or more than 100 tons gross carrying passengers for hire, except when operating as an administrative vessel. In 1980, there were 95,000 visitors to the park, 85 percent of whom were cruise ship passengers. In 2004, the total number of visitors had climbed to 350,000, of whom 91.6 percent were cruise visitors (figure 1). The total number of ships coming to Glacier Bay has been regulated by the park managers. (Figure 2 shows changes in cruise ship arrivals.) Up until 1996, the number of cruise ships was limited to 107 during peak months of June, July, and August. In 1997, the National Park Service allowed an increase to 139 ships. In 1997 a lawsuit was filed, arguing that increases were made without an EIS. In 2001, a federal appeals court ruled that the decision to increase ship limits violated the law and ordered completion of an EIS. Alaska's Senator Stevens petitioned Congress to allow 139 ships until completion of the EIS. The 2003 Record of Decision upheld entry limits of 139 vessels. These regulations limited the volume of cruise vessels entering the park; however, visitor levels have continued to rise due to the expansion in cruise ship capacity. The National Park Service does not regulate the size of cruise vessels entering park waters

Cruise ships are regulated as to when they can enter the park and how long they can spend there. Cruise ships must enter the park between 6:00 am and 10:00 am and generally spend about eight hours in the park. Most ships arrive between 6:00 and 7:30 am, although several ships come as late as 10:00 am. On days when two ships enter the park, ships may be staggered in their entry or may enter at the same time. In 2005, the two cruise ships arriving on Tuesdays both entered at 10:00 am; on Wednesdays, they staggered their entries at 7:00 am and 10:00 am, while on Thursdays, the two ships arrived at 6:00 am. There is some staggering of schedules to allow visitors of some vessels the opportunity to view the tidewater glacier without the presence of another vessel. These fixed schedules allow tour vessels, charter vessels and others to adjust their itineraries to some degree to avoid prolonged or frequent cruise ship encounters. The current schedule does not provide for days without the presence of cruise ships during peak season.

Cruise ships are permitted to enter non-wilderness waters of Glacier Bay National Park. Routes are restricted by the Park superintendent, and may be altered based on biological, physical, or other factors. Cruise ships typically follow a similar route from the vicinity of Bartlett Cove to Tarr Inlet and Margarie Glacier – in the western arm of Glacier Bay. They are regulated as to the times of day they are able to enter and exit the Park and the maximum speeds they are allowed to assume under various conditions. The Superintendent may impose speed restrictions based on biological or physical conditions in the Park, particularly when marine mammals may be disturbed. The cruise lines agreed to voluntary measures to avoid dumping of gray or black water in the boundaries of the National Park.

A smaller proportion of guests arrive by means other than the cruise ships. In 2004, there were 26,500 visitors to Glacier Bay who arrived by means other than cruise ships. Figure 4 shows trends in visitation by various visitor categories. Figure 5 shows trends in vessel arrivals among the five visitor segments.

Tour vessels are commercial vessels less than 100 tons gross used to transport passengers for hire, with more than 49 day passengers or 12 overnight passengers. A significant portion of these visitors (29 percent) rides on the 'day boat,' a catamaran run by a concessions firm out of Bartlett Cove. The day boat brings guests staying at the Glacier Bay Lodge or in nearby Gustavus into the park for an 8-hour tour. The day-boat also drops off kayakers and other backcountry users. Small cruise ships also are counted as tour vessels. Based on the FEIS, tour vessels are limited to 3 per day year round. Tour vessels may travel in both the west and east arms of Glacier Bay and may be affected by speed restrictions and wildlife buffers. In 2004, 20,807 park visitors were on tour vessels.

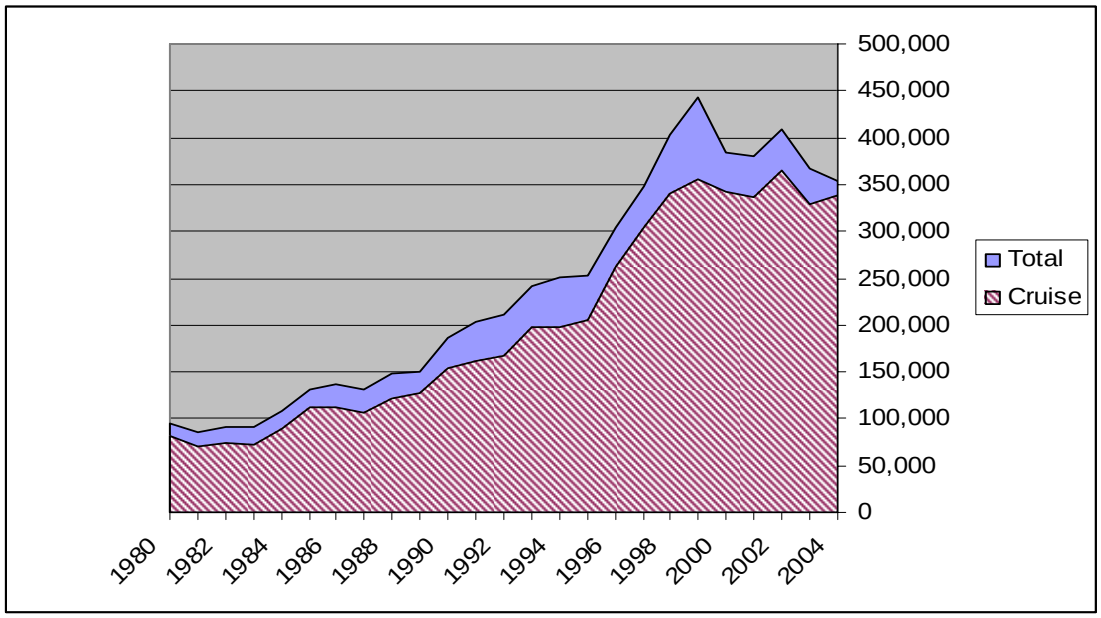
Charter vessels are less than 100 tons gross engaged in the transport of passengers for hire, and rated to carry up to 49 daily passengers or 12 overnight guests. These include whale watching tours, glacier sight-seeing tours, and charter fishing boats. During peak summer season, a limit of 6 charter boats daily is imposed, although no restrictions exist for other seasons. Charter vessels may visit any waterways in Glacier Bay that are accessible to motorized vessels. In 2004, 1,804 park visitors were on charter vessels. The number of actual charter vessels ranged between 300 and 400 in the 1990s, although fewer than 200 vessels were present in 2002.

Private vessels are non-commercial vessels with no size restrictions. Private vessels are limited to 25 per day in the peak season between June and August (2,300). Private vessels are allowed throughout the park, with the exception of wilderness waters, which only allow non-motorized vessels. Visitors arriving on private vessels are required to visit the park office for an orientation. In 2002, there were 1,734 private boaters.

Backcountry visitors are those independent travelers using non-motorized vessels, such as a kayak or canoe. They use designated wilderness areas, which may be accessed through wilderness and non-wilderness waters. Because of the lack of trails and the rugged terrain, few trails exist to take backcountry users far away from the shorelines. Thus, backcountry use is concentrated along shorelines and in campgrounds. In 2004, there were 1,152 backcountry permits issued to users and an additional 200 guided backcountry permits.

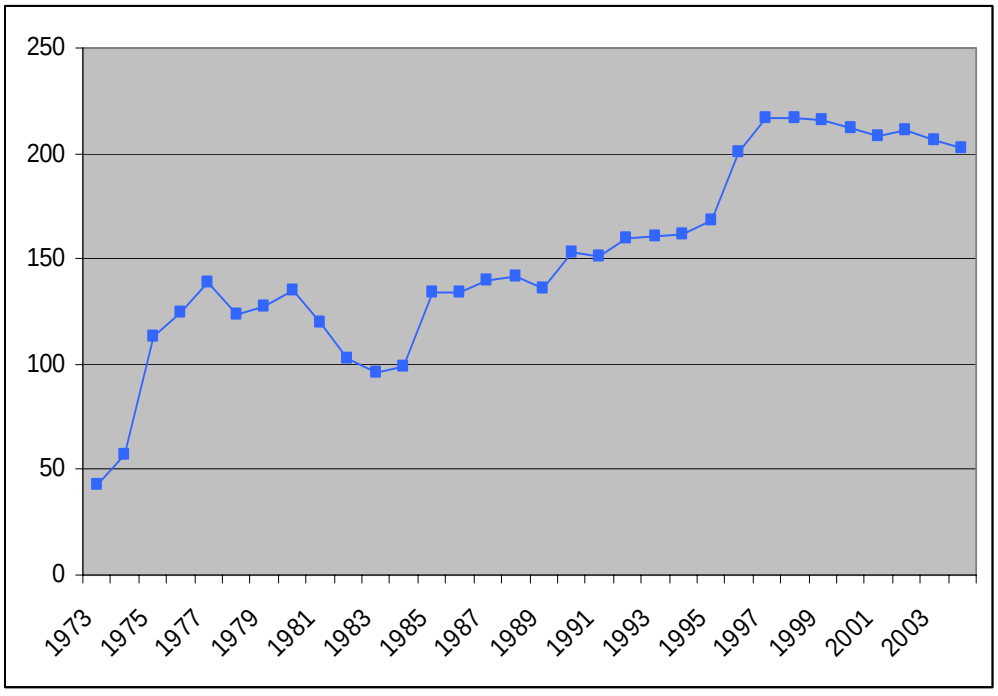
Backcountry use increased steadily throughout the 1980s and 1990s – peaking in 1995, with more than 3,300 visitors (figure 6). By 2002, this figure had fallen to 2,000 backcountry visitors. Data on overnight stays shows that the actual use of backcountry visitors exceeds other visitor segment (figure 7). These data also depict a general increase from 1980 to 1991, followed by a gradual decline. Commercially guided backcountry use has been constant since 1995, due to permit restrictions for Glacier Bay concessionaires. Limits to backcountry use were imposed in 1998, allowing a maximum of 2,200 backcountry visitors. These limits were established based on upward growth trends in the early 1990s. The limits were reduced in 1999 to 1,870 backcountry visitors, although visitor letters were fewer than 1,400 that year. In 2004, backcountry limits were eliminated entirely, but the permit system remains.

Figure 1. Visitor Traffic to Glacier Bay National Park: 1980-2004



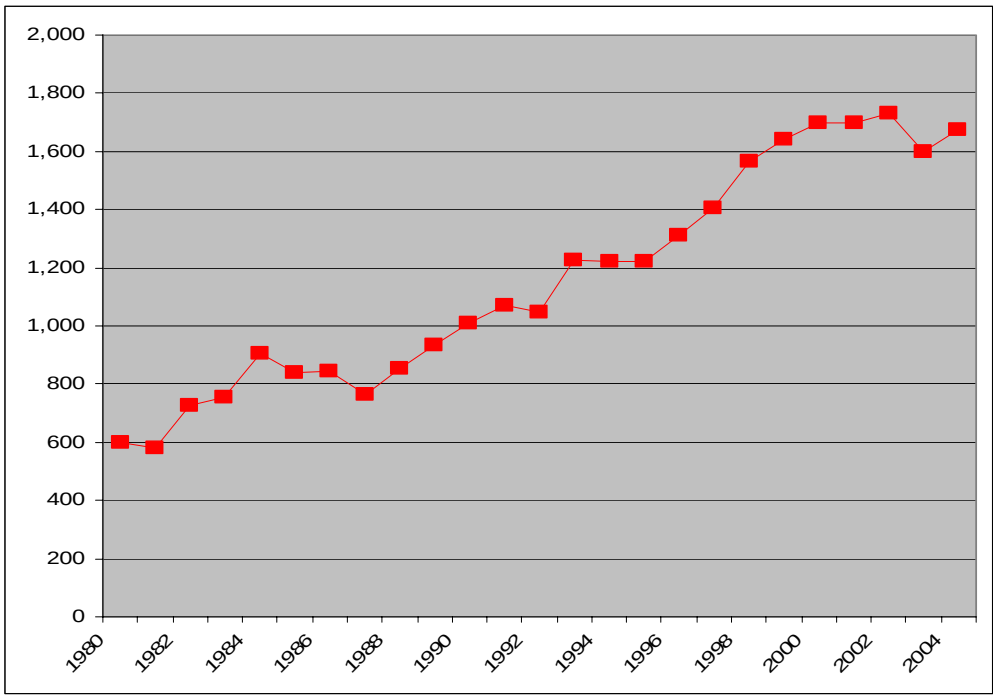
Source: Glacier Bay National Park (2005)

Figure 2. Number of cruise ships arriving in Glacier Bay: 1973-2003



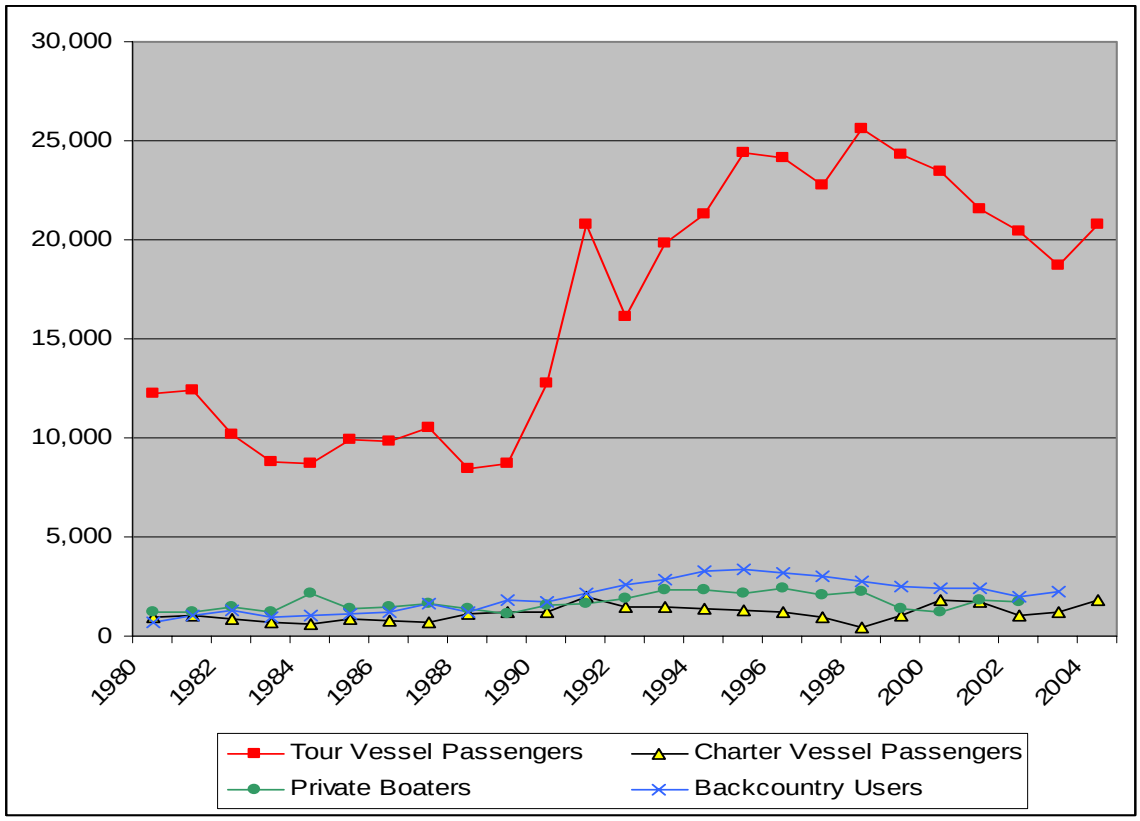
Source: Glacier Bay National Park (2005)

Figure 3. Average Number of Passengers per Ship: 1980-2004



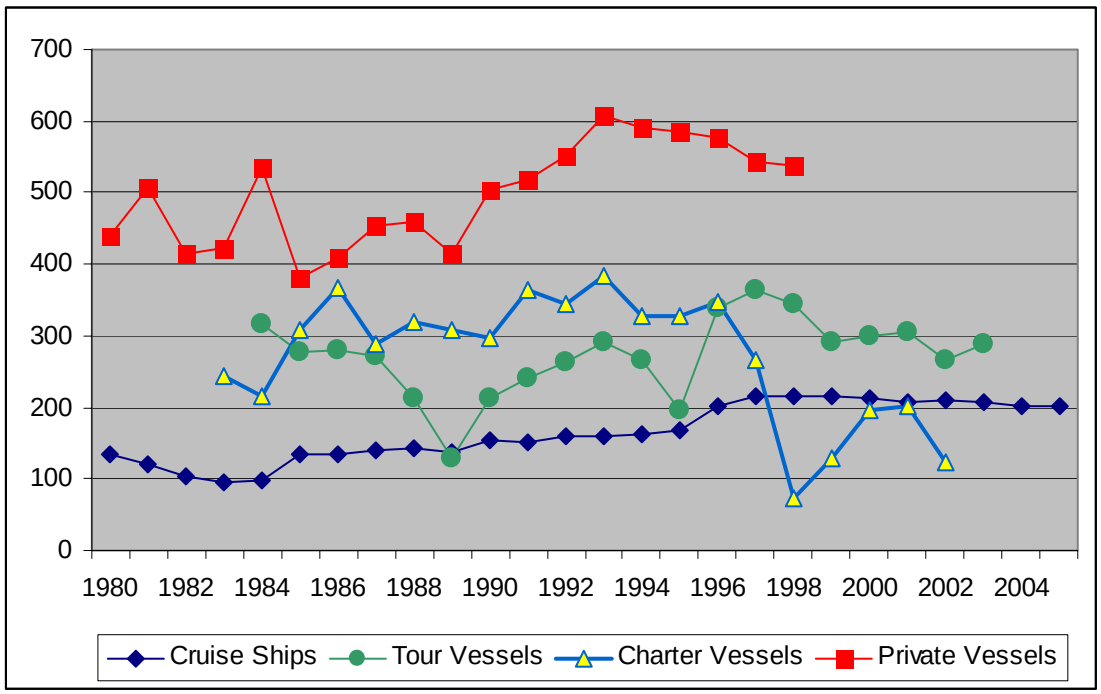
Source: Glacier Bay National Park (2005)

Figure 4. Non-cruise park visitors by visitor segment



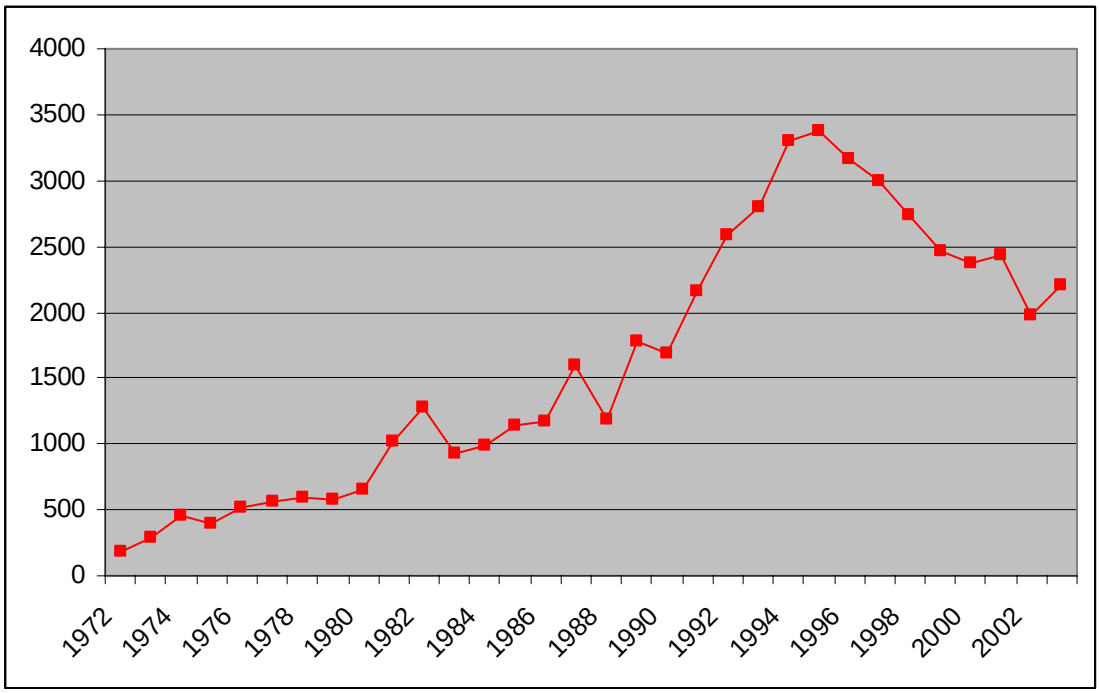
Source: Glacier Bay National Park (2005)

Figure 5. Vessel use among various visitor segments: 1980-2004



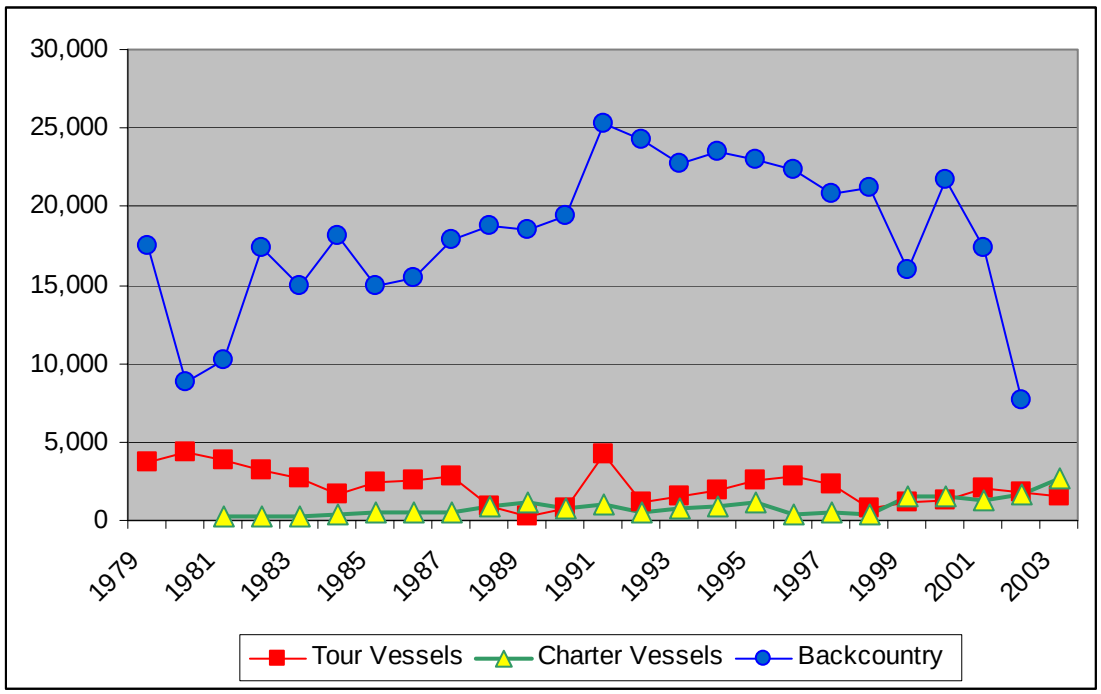
Source: Glacier Bay National Park (2005)

Figure 6. Backcountry visitors: 1972-2003



Source: Glacier Bay National Park (2005)

Figure 7. Overnight stays for visitor segments: 1979-2002



Source: Glacier Bay National Park (2005)

Table 1. Potential Cruise Ship Levels Projected to 2008 (based on 2004 levels)

	Annual Passengers	Ships	June-Aug. Passengers	Ships (Max. 139)	May/Sept Passengers	Ships (Max. 92)
Current Levels Scenario 1 Actual 2004 levels.	338,426	202	238,265	138	100,161	64
Current Levels Scenario 2 Assumes maximum ships visited *	384,033	231	240,053	139	143,980	92
Current Levels Scenario 3 Assumes maximum ships levels and increase in May/Sept bookings.	398,937	231	240,053	139	158,884	92
Current Levels Scenario 4 Assumes 3 percent annual increase in capacity [2004-08].	446,809	231	268,859	139	177,950	92
Current Levels Scenario 5 Assumes 7 percent annual increase in capacity [2004-08]	510,640	231	307,268	139	203,372	92
	Passengers	**Ships** (Max 306)	**Passengers**	**Ships** (Max. 184)	**Passengers**	**Ships** (Max. 122)
Future Levels Scenario 1 Assumes increase to FEIS levels and similar proportion of May/Sept traffic as in 2004.*	450,793	269	317,768	184	133,025	85
Future Levels Scenario 2 Assumes maximum increase to FEIS levels and maximum ships visited.*	508,698	306	317,768	184	190,930	122
Future Levels Scenario 3 Assumes increase in May/Sept bookings to peak season levels.	528,462	306	317,768	184	210,694	122
Future Levels Scenario 4 Assumes 3 percent annual increase in capacity [2004-08].	591,877	306	355,900	184	235,977	122
Future Levels Scenario 5 Assumes 7 percent annual increase in capacity [2004-08]	676,431	306	406,743	184	269,688	122

*Calculated based on the 2004 averages: 1,727 passengers/ship [June-Aug]; 1,565 passengers/ship [May/Sept.]

Chart Explanations

Current Levels Scenario 1. These figures are based on data provide by the National Park Service for 2004. The figures assume an average of 1,727 passengers per ship in peak season (June 1-August 31) and an average of 1,565 passengers in shoulder season (May and September). Shoulder season ships are operating at roughly two-thirds of the limit (64 ships of a maximum 92) and at about 90 percent capacity, based on the peak figures measuring passenger per ship. Note: Crew is not included in these calculations.

Current Levels Scenario 2. These calculations are based on 2004 levels, with similar assumptions about passenger levels in shoulder season. However, the ships visited in both peak and shoulder seasons have been increased to the current maximum allowed by the 2003 FEIS (92 ships).

Current Levels Scenario 3. These calculations are based on Scenario 2 assumptions using maximum shoulder season ship visits and include the potential for increase in ship capacity during shoulder season to match peak season levels – from 1,565 to 1,727.

Current Levels Scenario 4. These figures are based on Scenario 3 assumptions, with an additional 3 percent annual increase in cruise ship capacity for ships entering Glacier Bay from 2004 to 2008. This 3 percent is a conservative estimate of capacity increases based on analysis of capacity trends from 1980 to 2004. During this 25 year period, average annual passenger numbers grew at a rate of 7 percent, from an average of 601 passengers in 1980 to 1,729 in 2002, before leveling at 1,657. [See figure 2.]

Current Levels Scenario 5. These figures are based on Scenario 3 assumptions, with an additional 7 percent annual increase in cruise ship capacity for ships entering Glacier Bay from 2004 to 2008. This 7 percent is based on analysis of capacity trends from 1980 to 2004, when average annual passenger numbers grew from an average of 601 passengers in 1980 to 1,729 in 2002, before leveling at 1,657. [See figure 2.]

Future Levels Scenario 1. These calculations are based on the increase to maximum ship levels outlined by the 2003 FEIS, which are 184 ships during peak season and 122 ships during shoulder season. This scenario adopts the 2004 scenario assumptions, where cruise ships are operating at about 90 percent capacity in the shoulder season and about two-thirds of maximum allowed ships are arriving during shoulder season.

Future Levels Scenario 2. Similar to Scenario 2 for the Current Levels, these calculations assumed that the number of ships operating during shoulder season has increased to maximum capacity (122).

Future Levels Scenario 3. Similar to Scenario 3 for Current Levels, these figures are based on Scenario 2 levels and were calculated assuming an increase in ship capacity during shoulder season (1,565) to match peak season levels (1,727).

Future Levels Scenario 4. Similar to Scenario 4 for Current Levels, these figures are based on Scenario 3 levels, with an additional 3 percent annual increase in cruise ship capacity for ships entering Glacier Bay from 2004 to 2008.

Future Levels Scenario 5. These figures are based on Scenario 3 assumptions, with an additional 7 percent annual increase in cruise ship capacity for ships entering Glacier Bay from 2004 to 2008. This 7 percent is based on analysis of capacity trends from 1980 to 2004, when average annual passenger numbers grew from an average of 601 passengers in 1980 to 1,729 in 2002, before leveling at 1,657. [See figure 2.]

Appendix B:

Potential Impacts of Contaminants Derived from Cruise Ships on the Biological Resources of Glacier Bay

Potential Impacts of Contaminants Derived from Cruise ships on the Biological Resources of Glacier Bay

Literature Review Prepared for the
Glacier Bay National Park and Preserve
Vessel Management Science Advisory Board

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General Considerations

Measuring effects of environmental contaminant exposure in wildlife is challenging (McCarthy and Shugart 1990, Keller et al. 2000). Wild species are exposed to multiple stressors (e.g. food limitation, predation pressure) that can confound one's ability to understand contaminant effects on growth, reproduction and survival (Porter et al. 1984). In addition, environmental exposures to contaminants occur as mixtures of multiple compounds that may have synergistic, additive, or even antagonistic effects (Klaassen 1996, Rajapakse et al. 2002, Wade et al. 2002). Therefore, establishing contaminant-induced impacts from cruise ships to the biological resources of Glacier Bay is difficult. In order to understand the potential consequences of contaminant exposure from cruise ships, data need to be generated to: 1) establish that cruise ships are a source of contamination to Glacier bay, 2) document that cruise ship-derived contaminants have the *potential* to cause negative impacts on biological resources, and 3) document negative impacts from *potential* (since the direct source of the contaminant will most likely not be traced unequivocally back to cruise ships) cruise ship contaminants in Glacier Bay biota.

Johnson (2002) divides contaminant impacts from cruise ships into two categories, operational impacts and waste impacts. Operational impacts result in compromised air/water quality and leaching of toxic contaminants from antifouling paints. Waste impacts can be defined by categories regulated by the International Maritime Organization (IMO) such as oils, garbage, sewage, plastics, and hazardous substances. A zero waste disposal policy for plastics and hazardous materials is assumed to be complied with inside of Glacier Bay National Park. Therefore, effects from discharges such as plastics and hazardous materials (e.g., used for onboard printing, photo processing, etc.) are not discussed. A review of the available literature on waste and operational impacts related to cruise ship use in Glacier Bay can be further divided into four categories: discharges, anti-fouling agents, emissions, and oil. Following is a summary of the relevant articles pertaining to these four categories as well as some future research recommendations.

Critical Gaps in Knowledge and Prioritization of Suggested Research

Assessing environmental risk in an integrated process (Sekizawa et al. 2003, Suter et al. 2003) and usually requires several steps to determine the probability of an exposure causing a negative biological impact. Following are general recommendations to help guide research prioritization efforts for determining the potential impacts of contaminants derived from cruise ships on the biological resources of Glacier Bay:

1) Establish that cruise ships are a source of contamination to the bay: more complete monitoring of cruise ship emissions, discharges, and use of antifouling paint needs to be documented. For example, discharges should be screened for micro-contaminants such as pharmaceuticals, soaps, detergents, the use of anti-fouling paints should be regulated, and the amount of diesel engine emissions should be quantified.
2) Document that the cruise ship-derived contaminants have the *potential* to cause negative impacts on biological resources. Once the types and quantities of contaminants from cruise ships are better understood, existing data on the impacts of these contaminants can be used to assess the *potential* to cause a negative impact to the biological resources of Glacier Bay.
3) Document negative impacts from *potential* cruise ship contaminants. Conduct an environmental assessment to determine if the potential impacts linked to cruise ship contamination were evident in Glacier Bay biota. For example, the incidence of imposex (development of male sexual characteristics in females) could be evaluated for mollusks associated with tributyltin-contaminated sediment.

Summary of Impacts by Category

A. Discharges (gray water, black water, ballast water)

Discharges from cruise ships to Glacier Bay are highly regulated. Therefore, this report will focus on non-regulated contaminants in gray and treated black water that could potentially impact Glacier Bay biological resources. In addition, because of the extreme negative consequences that could arise from an introduction of an invasive species into Glacier Bay, monitoring cruise ship (as well as other ship) procedures for ballast water exchange is warranted. The transfer of dinoflagellates in ballast water from ships in Australian ports has been documented (Hallegraeff and Bolch 1991).

With respect to contamination from gray and treated black water discharges, I will focus on contaminants that are non-regulated and thus have the potential to be released into Glacier Bay. Contaminants of greatest concern appear to be micro-contaminants such as personal care products (soaps, lotions), pharmaceuticals, and drugs (e.g., caffeine). Because no data exist on the occurrence of non-regulated contaminants such as personal care products and pharmaceuticals in cruise ship discharge, the literature only provides evidence that these products are found in treated effluent (Kolpin et al. 2002, Pedersen et al. 2005) and thus have the potential to survive cruise ship waste treatment procedures.

Trace metals may also be discharged through gray and black water, however, no literature was available on the occurrence of metals in ship discharges. Therefore, for the following sections, the contaminants that will be addressed are these micro-contaminants that, to the best of my knowledge, are unregulated and not included in discharge screening practices. The contaminants reviewed are

1) *Personal care products:* sunscreen, perfumes, soaps, detergents, etc. Most, if not all, personal care products contain polycyclic musk compounds. Over the past decade, research has demonstrated that concern is warranted for toxic effects from these musk compounds to aquatic species (Balk and Ford 1999, Daughton 2004).
2) *Pharmaceuticals/drugs:* synthetic hormones, acetaminophen, caffeine, etc. Synthetic hormones resemble natural hormones and can disrupt endocrine function in aquatic organisms. Drugs, such as acetaminophen, can be converted (via well conserved enzyme classes, P450) to a toxic metabolite and cause cellular damage.

i) *mechanisms and pathways of transfer of contaminants*

Contaminants related to discharges will be released from the ship either in a dissolved phase or bound to organic particulate material.

1) Polycyclic musk compounds are lipophilic. Lipophilic compounds can cross cell membranes and be stored in fat, potentially being biomagnified up food webs. Polycyclic musks have been shown to bioaccumulate in marine organisms (Schreurs et al. 2004) and also become biomagnified up food webs to higher trophic-level species (Rimkus 1999).
2) Pharmaceuticals such as synthetic hormones can act as endocrine disruptors in many marine organisms. Endocrine disruptors include compounds that have structural similarities to estrogen (as well as other sex hormones) and are therefore capable of binding to these hormone receptors, potentially invoking a biological response (Witorsch 2002). Hundreds of chemicals that have estrogenic activity have been released into the environment (Colborn et al. 1993) and over the past decade increased public concern over wildlife and human health effects has resulted in research to identify endocrine disrupting compounds and their effects (Stancel et al. 1995, Jimenez 1997, Petit et al. 1997).

ii) *variability in susceptibility to different biota*

Musks and pharmaceuticals have the potential to accumulate and potentially cause a harmful effect across a wide range of taxa. Because these compounds are of new toxicological concern, there is limited data on the susceptibility of different organisms. Toxicity studies have examined lower-trophic level species (invertebrates, fish), although there is no evidence that these species are more susceptible. Lower trophic level species are more frequently used for toxicity studies due to lower cost and less stringent animal care requirements. Luckenbach (2005) showed that mussel gill tissue exposed to polycyclic musk compounds reduced the efficiency of a multi-drug transporter. This transporter is necessary for exporting unwanted chemicals out of the cell. Reduced (or

blocked) transporter efficiency can result in a buildup of toxic compounds inside the cell, causing cellular dysfunction and eventual cell death.

iii) *evidence of taxa-specific effects on fitness*

Schreurs (2004) showed that polycyclic musk compounds are able to exert anti-estrogenic effects in zebrafish under laboratory conditions. The finding that musk compounds exert endocrine-disrupting behavior in fish suggests that these contaminants can alter reproductive potential. Through the same general mechanism, synthetic hormones and other compounds that can mimic hormone function also have the potential to reduce reproductive success.

iv) *research recommendations*

1) Screening discharge for a range of potential contaminants such as polycyclic musk compounds, synthetic hormones (and other pharmaceuticals) (Balk and Ford 1999) would determine if cruise ship discharge had the potential to impact Glacier Bay biological resources.
2) Monitor Glacier Bay sediments for these micro-contaminants as well as metals (copper, lead, cadmium, etc.) (Long et al. 1995).
3) Rimkus (1999) reports on the existence of detectable amounts of musk fragrance compounds in marine biota such as mussels, shrimp, and fish, which might prove useful for comparative assessment with organisms in Glacier Bay.

B. Anti-fouling agents

Anti-fouling agents are used to prevent attachment and growth of organisms on ships, anchor chains, etc. Tributyltin is widely used in paint as an anti-fouling agent and its impact in the marine environment has been recognized for years. U.S. cruise ships may be able to use this compound as an anti-fouling agent, provided some restrictions are met (Fent 1996). Even though shipyards, docks, and harbors are known to be local point sources for tributyltin, environmental measurements show that open bays also have measurable tributyltin levels. Given the low toxicity threshold observed for tributyltin on marine organisms (Fent 1996), the possibility exists that tributyltin leaching from cruise ships could be detrimental to marine life in Glacier Bay.

i) *mechanisms and pathways of transfer of contaminants*

Tributyltin is a class of organotins and exhibit lipophilic properties (affinity for organic compounds, bioaccumulation). Organisms that appear to be most susceptible are benthic species, which are exposed from organotin accumulation in sediments or on bacterial biofilms (Labare et al. 1997). In addition, predator species (e.g., sea otters) that eat these benthic organisms can be at risk for increased exposure (Kannan et al. 1998).

ii) variability in susceptibility to different biota

A vast amount of toxicity data exist on the impacts of tributyltin. Based on available literature the following organisms may be especially sensitive:

1) Mollusks appear very sensitive to toxic exposure and thus used frequently as environmental monitors.
2) Sea otters are believed to be at risk for accumulating high concentrations of butyltin compounds because of their bottom-feeding habits and a diet that consists of invertebrates such as mollusks and gastropods (Kannan et al. 1998). Furthermore, sea otters small body size, lack of blubber, and high metabolic requirements (sea otters consume an amount of food equal to approximately 20-30% of their body weight each day), also make them prone to accumulating large quantities of toxic compounds from their prey in a short time period.

iii) evidence of taxa-specific effects on fitness

1) Mollusks. Tributyltin has been shown to cause reduced fitness in mollusks. Population crashes have been observed in dogwhelks, which appear to be highly sensitive to tributyltin toxicity (Fent 1996). Organotins are able to disrupt the reproductive capability of these mollusks, causing imposex (development of male sex characteristics in females) and in more severe cases, sterility.
2) Sea otters appear to accumulate elevated concentrations of tributyltin, perhaps due to their high metabolic rate and diet. Kannan et al. (1998) found significantly higher butyltin concentrations in sea otters that died of infectious diseases compared to those that died of trauma (mean =1570 ng/g versus 220 ng/g), suggesting butyltin exposure increased their susceptibility to disease and infection.

iv) research recommendations

1) Evaluate sediment samples for organotin concentrations in areas that are frequented by cruise ships (i.e. mooring locations, etc.) and compare levels to previously reported data, e.g. Fent (1996), Bhosle et al. (2004) to determine if these concentrations are of concern.
2) Monitor mollusks in regions identified by organotin measurements, for signs of imposex. Terlizzi et al. (2004) provides a scoring method for the degree of imposex measured in the gastropod, *Hexaplex trunculus*, that might be a useful reference for monitoring imposex in Glacier Bay organisms.
3) Measure organotin concentrations in dead marine mammals found within the park.

C. Emissions

The literature obtained on impacts from cruise ship emissions was divided into two groups:

1) model-based approaches, which estimated the amount of emissions, and

2) dose-response toxicity studies that evaluated the consequences of exposure to diesel emissions. The emissions from cruise ships of concern are nitrogen oxides, sulphur dioxide, and carbon monoxide.

i) mechanisms and pathways of transfer of contaminants

The primary pathway for exposure to cruise ship emissions would be via inhalation. As such, the lung is the primary target organ for toxic effects. Environmental (i.e. low-level) exposure to diesel fuel has been shown to decrease lung bacterial clearance in mice (Harrod et al. 2005); however, these results were a bit inconclusive as an effect was observed in mice exposed for one week but not six months. Human health assessments have found correlations between diesel fuel emission exposure and effects such as cancer and respiratory disease (Kagawa 2002).

ii) variability in susceptibility to different biota

No relevant data were available to determine variability in susceptibility of different biota in Glacier Bay. Nonetheless, because the primary route of exposure to cruise ship emissions is through inhalation, air-breathing organisms are at greatest risk for toxic effects from diesel fuel emissions.

iii) evidence of taxa-specific effects on fitness

No relevant data were available to provide evidence of taxa-specific effects on fitness to Glacier Bay biological resources.

iv) research recommendations

1) Estimate the amount of emissions from cruise ships operating in Glacier Bay. These estimations can be based on engine size (Corbett and Koehler 2003) and the amount of time the cruise ship spends operating these engines (Saxe and Larsen 2004). Based on these estimates, the increase in yearly (or seasonal) emissions from cruise ships to Glacier Bay can be calculated.

D. Oil

Oil can be released into Glacier Bay from cruise ships in three ways: 1) A cruise ship can wreck, creating a significant oil spill. The risk of a major oil spill from a cruise ship in Glacier Bay is slim, although the devastating consequences to the Glacier Bay ecosystem allow for a brief mention of impacts from oil on marine biota. 2) A minor oil spill from a malfunctioning oil:water separator or emergency situation (where oil is deliberately released). 3) Regulated discharge of low level oil contaminated water. Even though this bilge waste is tightly regulated, over the past decade a number of cruise lines have been cited for illegal discharge of oily bilge water, garbage and other waste. In fact, four

major cruise liners were fined for illegal discharge of wastewater in 2001 and 2002 in Juneau Alaska (Sweeting and Wayne). In addition, laboratory studies have shown that even low-level oil exposure can cause detrimental impacts to marine organisms (Carls et al. 1999).

i) mechanisms and pathways of transfer of contaminants

Oil is composed of polycyclic aromatic hydrocarbons (PAHs), some of which are lipophilic compounds and able to bioaccumulate in tissue. The transfer pathway of oil will depend on how the organism is exposed, as well as the character of the oil, or PAH. For example, seabirds or sea otters exposed to crude oil will be acutely affected by loosing thermoregulation capabilities because of the oil's direct effect on feathers/hair. However, long-term low-level exposure to diluted oil (through ingestion, filter-feeding, across gills, etc.) could result in less obvious physiological changes such as endocrine disruption, immune alteration, and potentially cancer.

ii) variability in susceptibility to different biota

Acute exposure to a significant oil spill will result in mortality across a wide range of taxa (seabirds, sea otters, fish, crustaceans, etc.) as evidenced by the Exxon Valdez oil spill. Organisms most susceptible to chronic, low-level exposure appear to be those associated with sediment. Peterson et al. (2003) reported that long-term population impacts were observed in sediment-affiliated species (fish, sea otters, sea ducks) as well as pink salmon many years following the Exxon Valdez oil spill.

iii) evidence of taxa-specific effects on fitness

Studies have shown that low-level PAH exposure during fish development causes decreases in egg/larval survival (Carls et al. 1999) as well as reduced marine survival to maturity (Heintz et al. 2000).

iv) research recommendations

1) PAHs from cruise ship discharges to Glacier Bay are most likely not substantial enough to cause a negative impact, as long as the PAH discharge level is closely monitored and regulated. A comprehensive assessment on PAH compounds in cruise ship discharge would help to establish that acceptable levels are not being exceeded.
2) A model-based approach, similar to those preformed by French-McCay (2004), could help to predict the negative consequences to Glacier Bay's biological resources. Recommendations to reduce risk of a major oil spill could include mandatory double hulls for any cruise ship caring over a specified amount of oil into Glacier Bay.

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Wade, M. G., S. Parent, K. W. Finnson, W. Foster, E. Younglai, A. McMahon, D. G. Cyr, and C. Hughes. 2002. Thyroid toxicity due to subchronic exposure to a complex mixture of 16 organochlorines, lead, and cadmium. Toxicological Sciences 67:207-218.

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Anti-fouling agents. Alzieu presents a concise review of tributyltin. Although not as thorough as Fent's synthesis, Alzieu's summary discusses some important aspects about the toxicity and environmental fate of tributyltin. Data from ecotoxicology studies show tributyltin is stable in the marine environment (from a few days to months) and no effect levels for mollusks may be as low as 1ng/L. Alzieu also presents evidence that regulatory bans on tributyltin use have proven effective at reducing toxic effects in marine organisms. This review provides some comparative data that could be used if marine organisms are monitored for tributyltin levels in Glacier Bay. Rigor Score = R

Balk, F., and R. A. Ford. 1999. Environmental risk assessment for the polycyclic musks, AHTN and HHCB - II. Effect assessment and risk characterization. Toxicology Letters 111:81-94.

Discharges. Balk and Ford provide evidence of environmental effects from polycyclic musk compounds that can be used for risk characterization. Results are presented from several studies using multiple species, such as algae, daphnia, and fish, to determine the toxic effect dose (i.e. the dose at which an adverse effect is observed) for two different polycyclic musks, AHTN and HHCB. In addition, symptoms before the onset of death in exposed fish such as loss of equilibrium, enhanced and/or irregular respiration, and cessation of food intake are reported. Data presented could prove an important reference for comparison if levels of polycyclic musk compounds were to be assessed in Glacier Bay biota. Rigor Score = 2

Beaumont, A. R., and P. B. Newman. 1986. Low-Levels of Tributyl Tin Reduce Growth of Marine Microalgae. Marine Pollution Bulletin 17:457-461.

Anti-fouling agents. Beaumont and Newman present the results from their study on the effects of tributyltin on marine microalgae growth. Three species of micro-algae were used in the trials: *Pavlova lutheri* (Droop) Green, *Dunaliella tertiolecta* Butcher, and *Skeletonema costatum* (Grev.). Micro-algae were cultured in flasks and exposed to 0, 0.1, 1, or 5, µg/L tributyltin. The authors found that death occurred within 2 days for micro-algae exposed to the highest tributyltin concentration (5 µg/L) and growth was reduced for all three species exposed to 1 µg/L. *S. costatum* appeared to be the most sensitive species as virtually no growth occurred in cultures exposed to 0.1 µg/L tributyltin, whereas growth of the other two species was slightly, though significantly, reduced, compared to controls. In addition, because they found in one of the culture flasks that as much as half the tributyltin was adsorbed onto the walls of the flask, they feel their results underestimate tributyltin toxic effects. This study demonstrates the toxic potential of low concentrations of tributyltin on three micro-algae species and that micro-algae exhibit a difference in tributyltin tolerance. Rigor Score = 4

Bhosle, N. B., A. Garg, S. Jadhav, R. Harjee, S. S. Sawant, K. Venkat, and A. C. Anil. 2004. Butyltins in water, biofilm, animals and sediments of the west coast of India. Chemosphere 57:897-907.

Anti-fouling agents. Bhosle et al. report butyltin concentrations measured in seawater, sediments, and biota (oyster, mussel, clam, fish) from 20 locations off the west coast of India. For the animals sampled, butyltins (dibutyltin and tributyltin combined) ranged between 58 and 825 ng/g dry weight in tissue. Mussels contained the highest concentrations of butylitns (825 ng/g dry wt tissue), whereas the highest tributyltin concentration was recorded in oysters (732 ng/g dry wt). The authors also present results from an experiment conducted to assess the role of biofilm as a vehicle for tributyltin transfer to higher trophic-level organisms. Tributyltin was added to a culture of biofilm, which was then fed to the clam *Paphia malabarica*. Results

showed that tributyltin did accumulate in the clam over a period of 24 hours. Bhosle and coauthors provide data on dibutyltin and tributyltin concentrations in seawater, sediments, biota (oyster, mussel, clam, fish), which could prove useful for comparison if samples are evaluated for butyltin concentrations in Glacier Bay. Rigor Score = 3

Bruchet, A., C. Prompsy, G. Filippi, and A. Souali. 2002. A broad spectrum analytical scheme for the screening of endocrine disruptors (EDs), pharmaceuticals and personal care products in wastewaters and natural waters. Water Science and Technology 46:97-104.

Discharges. Bruchet et al. describe an analytical approach for the screening of contamiants such as pharmaceuticals and personal care products in water systems. Their main objective was to implement an analytical scheme capable of identifiying as many micropollutants (e.g., pharmaceuticals, caffeine, detergents, soap) as possible in a single water sample to establish basline data. The authors report the application of this shceme to wastwater and natural water systems as well as discuss the measurements of several contaminant compounds. A variety of contaminants including phthalates, nonylphenols, caffeine, nicotine, photohormones, synthetic estrogens, and sunscreen agents were identified in the water samples. Many of these compounds are known to be endocrine disruptors. The described analytical scheme may prove useful if discharge samples from cruise ships are proposed to be evaluated for contaminant compounds similar to those reported here. Several papers in this review discuss the impacts of contaminants such as pharmaceuticals and personal care products on marine life. Rigor Score = 1

Carls, M. G., S. D. Rice, and J. E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (*Clupea pallasi*). Environmental Toxicology and Chemistry 18:481-493.

Oil. Carls et al. provide experimental data to demonstrate the sensitivity of Pacific herring (*Clupea pallasi*) to polynuclear aromatic hydrocarbons (PAHs) found in weathered crude oil. One goal of the experiment was to simulate conditions observed in Prince William Sound following the Exxon Valdez oil spill. They exposed Pacific herring eggs to a range of PAH concentrations (aqueous), incubated the eggs to hatching, and evaluated a variety of toxicological endpoints (e.g., hatching ability, genetic damage, swimming ability). Carls and coauthors found that exposure to PAH concentrations of 0.7 parts per billion (ppb) caused malformations, genetic damage, mortality, and decreased size and swimming ability in the larval herring. Furthermore, concentrations as low as 0.4 ppb caused sublethal effects such as yolk sac edema and immaturity consistent with premature hatching. These data provide evidence that low (0.4 ppb) levels of PAH exposure can induce negative biological effects (both lethal and sublethal) in Pacific herring. Rigor Score = 4

Corbett, J. J., and H. W. Koehler. 2003. Updated emissions from ocean shipping. Journal of Geophysical Research-Atmospheres 108 (9): 1-15.

Emissions. Corbett and Koehler use a rigorous 'bottom-up' approach to update the current emissions from internationally registered ships. Their updated inventories increase the previously reported ship emission rates for all pollutants, such as global production of nitrogen oxides (NO_x), by a factor of 2. Corbett and Koehler's approach uses engine power and vessel activity to compute fuel consumption for internationally registered ships. Based on their analyses, the world fleet fuel consumption, calculated for all main and auxiliary marine engines in all internationally registered vessels, is ~ 289 million metric tons annually. The approach used in this study to estimate ship emission rates could be applied to cruise ships entering Glacier Bay in order to estimate cruise ship emissions to the Glacier Bay area. Rigor Score = 2

Daughton, C. G. 2004. Non-regulated water contaminants: emerging research. Environmental Impact Assessment Review 24:711-732.

Discharges. Daughton reviews research on emerging chemical pollutants. Included in Daughton's review is a section on "Pollution from personal actions, activities, and behaviors" (Section 1.3.), which discusses the acceptance of personal care products and pharmaceuticals as environmental pollutants. This review is an attempt to discuss contaminant exposure and potential risk using a holistic approach and provides some insight into society's relationship with chemical pollutants. Rigor Score = R

Derwent, R. G., D. S. Stevenson, R. M. Doherty, W. J. Collins, M. G. Sanderson, C. E. Johnson, J. Cofala, R. Mechler, M. Amann, and F. J. Dentener. 2005. The contribution from shipping emissions to air quality and acid deposition in Europe. Ambio 34:54-59.

Emissions. Derwent and coauthors use a global three-dimensional Lagrangian chemistry-transport model (STOCHEM) to describe the contributions of shipping emissions (from SO2, NOx, VOCs and CO in the year 2000) along the Atlantic Ocean seaboard to European regional acid deposition and ozone air quality. Calculations were made for the acid deposition and ozone formation by international shipping. The authors conclude that shipping emissions act as a major external influence on Europe's air quality and contribute to the seasonal exceedance of ozone critical levels set for the protection of human health. This paper demonstrates that emissions from shipping can contribute to reduced air quality and increased ozone production. Rigor Score = 2

Dyrynda, E. A., R. J. Law, P. E. J. Dyrynda, C. A. Kelly, R. K. Pipe, and N. A. Ratcliffe. 2000. Changes in immune parameters of natural mussel *Mytilus edulis* populations following a major oil spill ('Sea Empress', Wales, UK). Marine Ecology-Progress Series 206:155-170.

Oil. Dyrynda et al describe results from their study that monitored ecological effects from the 'Sea Empress' oil spill off the coast of Wales, UK in 1996. Four sites were sampled during the study period, three of the sites were 'oiled' and one was used as a control. The effects of oil on mussel (*Mytilus edulis*) immunity was evaluated in parallel with PAH contaminant measurements in mussel tissues. Mussel immunity was assessed by measuring haemocyte superoxide generation (used for killing pathogens) and phagocytic activity. Dyrynda and coauthors report that there was a significant reduction in superoxide generation and phagocytosis in haemocytes from oiled mussels. They conclude that this reduction in mussel immunity may inhibit disease resistance. Results presented here also demonstrate a recovery of immune function and reduction in tissue PAH concentrations approximately three to four months after the spill. These data 1) demonstrate that PAHs caused reduced immune function in mussels and 2) provide a timeframe for mussel immune function recovery after an oil spill. Rigor Score = 3

Fent, K. 1996. Ecotoxicology of organotin compounds. Critical Reviews in Toxicology 26:3-117.

Anti-fouling agents. Fent provides an exhaustive (~115 pages) overview and synthesis of results from 7 years of his studies on the ecotoxicology of organotin compounds. The objective of this review is to develop an ecotoxicological concept on the aquatic toxicology of organotin compounds focusing on an integrated approach that includes environmental chemistry, toxicology, and ecology. Included in this synthesis are sections describing 1) organotin production and applications, 2) environmental chemical aspects, 3) occurrence, distribution, and fate in aquatic environments, 4) fundamental ecotoxicological concepts (uptake and fate of organotins in aquatic organisms), 5) molecular, biochemical, and cellular effects: mechanisms of action, 6) effects on aquatic organisms (general toxicity), and 7) effects on populations, communities, and ecosystems. Rigor Score = R

French-McCay, D. P. 2004. Oil spill impact modeling: Development and validation. Environmental Toxicology and Chemistry 23:2441-2456.

Oil. French-McCay summarizes existing information to develop a model for the estimation of impacts to habitats, wildlife (e.g., seabirds, sea otters), and aquatic organisms from acute oil exposure, such as what would occur from an oil spill. Two models are presented, a physical fates model and a biological effects model. The physical fates model estimates the distribution of oil on water surface, shorelines, water column, sediments and accounts for the fate and transport of dispersed oil compounds. The biological effects model estimates exposure (from floating oil and subsurface contamination) to biota of several behavior types (e.g., fish invertebrates, seabirds, sea otters, etc.) as well as different age classes for multiple species. Impacts are summarized as areas or volumes affected, percent of populations lost, and production foregone due to the spill's effects. Models such as the one described in this study could prove useful to help estimate the impact of an oil spill on the biota of Glacier Bay. Rigor Score = 2

Hall, L. W., J. M. Giddings, K. R. Solomon, and R. Balcomb. 1999. An ecological risk assessment for the use of Irgarol 1051 as an algaecide for antifoulant paints. Critical Reviews in Toxicology 29:367-437.

Anti-fouling agents. Hall et al. presents an ecological risk assessment for the use of Irgarol 1051. Irgarol 1051 is used as an algaecide in antifouling paints. In 1998 the first antifouling paints containing Irgarol 1051 were registered for use in the U.S. Hall and coauthors use exposure data derived from 11 monitoring studies (146 stations) conducted in marinas, estuaries, and coastal waters from 1992 to 1997 in six European countries. Because Irgarol 1051 is a photosynthesis-inhibiting herbicide, toxicity appears to be much greater to plants than animals. The author’s assessment concludes that the threshold for chronic toxicity for aquatic animals (approximately 4000 ng/l) is unlikely to be exceeded in the environment, however they caution that because rainbow trout appear to be highly sensitive to Irgarol 1051's toxicity, additional studies with a representative saltwater fish species are recommended. Hall and coauthors' risk assessment provides an extensive review of environmental concentrations and toxicity data for Irgarol 1051. Rigor Score = 2

Hallegraeff, G. M., and C. J. Bolch. 1991. Transport of Toxic Dinoflagellate Cysts Via Ships Ballast Water. Marine Pollution Bulletin 22:27-30.

Discharges. Hallegraeff and Bolch report on the incidence of toxic dinoflagellate cysts in ship ballast water to test the hypothesis that the recent appearance of three species of toxic dinoflagellates in Australian estuaries was from introduction via ship transport. The Australian Quarantine and Inspection Service sampled over 200 ballast tanks of cargo vessels and at the time of the study found that 31 of the 83 cargo hold samples contained dinoflagellate cysts. This study demonstrates that introduction of exotic species, such as toxic phytoplankton, is feasible through discharge of ballast water. Although discharge of ballast water into Glacier Bay may not be occurring, the ramifications of the introduction of exotic species, particularly toxic plankton, could be substantial to the Glacier Bay ecosystem and should be noted. Rigor Score = 2

Harrod, K. S., R. J. Jaramillo, J. A. Berger, A. P. Gigliotti, S. K. Seilkop, and M. D. Reed. 2005. Inhaled diesel engine emissions reduce bacterial clearance and exacerbate lung disease to *Pseudomonas aeruginosa* infection in vivo. Toxicological Sciences 83:155-165.

Emissions. Harrod et al. investigated the ability for mice to clear the bacteria *Pseudomonas aeruginosa* following inhalation exposure (continuously for either one week or six months) to diesel engine emissions. The exposures were conducted seven days per week, 6 h/day and included five treatment groups: four dilutions of engine exhaust and clean air (control). Target exposures were set at 30 (low), 100 (mid-low), 300 (mid-high), and 1000 (high) mg/m3 PM. *Pseudomonas aeruginosa* was instilled into the respiratory track of exposed and control

mice and lung bacterial clearance was measured 18 hours later by measuring lung bacterial titers. Harrod et al. found that lung clearance was significantly reduced in mice exposed to diesel engine emissions for one week ($P = 0.002$, $n = 20$ per exposure group), with a noticeable reduction in clearance ability in the in the low (30 mg/m3 PM) exposed group. Interestingly, there was no significant reduction in bacterial clearance in mice exposed for six months ($P = 0.453$, $n = 10$ per exposure group). The authors' findings indicate that environmental levels of diesel engine emissions can decrease bacterial clearance from the lungs and increase lung pathogenesis during a pulmonary bacterial infection. This study demonstrates that ambient environmental exposures of diesel engine emissions cause a measurable impact on bacterial resistance in mice. However, the applicability of these results to marine life exposed to cruise ship diesel engine emissions in Glacier Bay is unknown. Rigor Score = 4

Heintz, R. A., S. D. Rice, A. C. Wertheimer, R. F. Bradshaw, F. P. Thrower, J. E. Joyce, and J. W. Short. 2000. Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha* after exposure to crude oil during embryonic development. Marine Ecology-Progress Series 208:205-216.

Oil. Heintz et al. report on results obtained from two complimentary studies, one on growth and one on survival, of pink salmon (*Oncorhynchus gorbuscha*) following embryonic exposure to crude oil. In order to examine effects of crude oil on growth, salmon eggs were incubated with crude oil (PAH) concentrations of either 0, <5.2 parts per billion (ppb), or <19.4 ppb. The growth rate was calculated after the fish were approximately 10 months old. Heintz et al. found a significant (P <0.001) effect of embryonic crude oil exposure on pink salmon growth rate. Marine survival was calculated using a mark-recapture method on hatchery-raised salmon. Fish were tagged (~210,000 fish) and their survival was determined by counting the number of fish that survived to maturity. Pink salmon exposed to PAHs at ~5.4 ppb were found to have a 15% decrease in marine survival, compared to unexposed fish. One significant outcome of this research is that PAH exposure appeared to have delayed effects on the growth and marine survival of pink salmon. The results presented here demonstrate that low level (~5.4 ppb) PAH exposure can cause significant, delayed, detrimental effects in pink salmon. Rigor Score = 4

Johnson, D. 2002. Environmentally sustainable cruise tourism: a reality check. Marine Policy 26:261-270.

General. Johnson discusses and categorizes the environmental impacts from the cruise ship industry as well as suggests potential strategies that can be used by both cruise line operators and cruise tourism destinations to ameliorate these impacts. Of relevance to this review, operational impacts include antifouling as well as water and air quality pollution. In addition, the four types of waste from cruise ships characterized in The International Convention for the Prevention of Pollution from Ships (MARPOL Protocol) are listed as oils, garbage, sewage, plastics and hazardous substances. Johnson's discussion may prove a useful summary of the many impacts (including socio-economical) that result from the cruise ship industry. Rigor Score = R.

Kagawa, J. 2002. Health effects of diesel exhaust emissions - a mixture of air pollutants of worldwide concern. Toxicology 181:349-353.

Emissions. Kagawa provides a review of the data on health effects from diesel exhaust emissions. Included is a summary of evidence for human health risks, both from cancer and respiratory disease (decreased pulmonary function as well as bronchitis-like and asthma-like symptoms). Kagawa states that regulation of diesel exhaust, particularly particles, seems necessary as a means of protecting human health since evidence shows diesel exhaust particles appear to have the greatest effect on human health. Rigor Score = R

Kannan, K., K. S. Guruge, N. J. Thomas, S. Tanabe, and J. P. Giesy. 1998. Butyltin residues in southern sea otters (*Enhydra lutris nereis*) found dead along California coastal waters. Environmental Science & Technology 32:1169-1175.

Anti-fouling agents. Kannan et al. conduct butyltin analyses of tissue samples collected from dead sea otters (n = 35) found along the coast of California between the years 1992-1996. Butyltin (sum of monobutyltin, dibutyltin and tributyltin) concentrations in sea otter livers ranged from 40 to 9200 ng/g wet wt. Gender and sampling location contributed to the observed variability in sea otter liver tissue, for example, Sea otters collected from enclosed marinas such as Monterey Harbor and Morro Bay contained at least an order of magnitude greater concentrations than those from open locations. Sea otters are believed to be at risk for accumulating high concentrations of butyltin compounds because of their bottom-feeding habits and because their diet consists of invertebrates such as mollusks and gastropods. One interesting finding of this study was that sea otters that died of infectious diseases contained significantly (P < 0.05) higher butyltin concentrations than those that died of trauma (mean =1570 ng/g versus 220 ng/g), suggesting butyltin exposure impaired resistance to disease and infection. This study documents elevated butyltin concentrations in sea otters as well as implies that butyltin exposure is impairing sea otter immune function. Rigor Score =3

Katranitsas, A., J. Castritsi-Catharios, and G. Persoone. 2003. The effects of a copper-based antifouling paint on mortality and enzymatic activity of a non-target marine organism. Marine Pollution Bulletin 46:1491-1494.

Anti-fouling agents. Katranitsas et al. assess the toxicological impact of the antifouling paint Flexgard VI-II using brine shrimp (*Artemia*) nauplii as a test organism. Flexgard VI-II is a copper-based antifouling paint produced by the company Flexabar. Brine shrimp nauplii, in test vessels with artificial seawater, were exposed to PVC panels painted with Flexgard VI-II. Brine shrimp appeared to be highly sensitive to Flexgard VI-II toxicity as evidenced by the low lethal concentration dose needed to kill 50% of the test organisms (LC_{50}). The authors used a surface (of the painted PVC panels) to volume (of seawater) calculation to determine the LC_{50}. The surface to volume LC_{50} (24 h) calculated was 24.6 mm^2/ml with 21.7–26.9 mm^2/ml as 95% confidence limits. Exposed brine shrimp nauplii also exhibited decreased ATPase enzymatic activities. Based on the results from their study, the authors conclude that the copper-based antifouling paint, Flexgard VI-II is substantially toxic to *Artemia* nauplii. Rigor Score = 4

Kolpin, D. W., E. T. Furlong, M. T. Meyer, E. M. Thurman, S. D. Zaugg, L. B. Barber, and H. T. Buxton. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: A national reconnaissance. Environmental Science & Technology 36:1202-1211.

Discharges. Koplin and coauthors describe the first nationwide survey of the occurrence of organic wastewater contaminants (OWC), such as pharmaceuticals and hormones, in water resources. They describe the U.S. Geological Survey's newly developed analytical methods to measures concentrations of 95 OWC compounds in water. The authors report that one or more OWC was detected in 80% of the 139 streams sampled. Their results demonstrate that OWCs are detectable in U.S. streams at the national scale and imply that these compounds survive wastewater treatment and biodegradation. This study is a comprehensive documentation of the types of OWC contaminants detected in waterways and could prove useful to the Glacier Bay National Park Board if screening for OWCs was to be proposed for cruise ship discharge. Rigor = 1

Labare, M. L., S. L. Coon, C. Matthias, and R. M. Weiner. 1997. Magnification of tributyltin toxicity to oyster larvae by bioconcentration in biofilms of Shewanella colwelliana. Applied and Environmental Microbiology 63:4107-4110.

Anti-fouling agents. The goal of this study was to compare the toxic effects of dissolved and bioconcentrated tributyltin on oyster larvae. Bioconcentrated tributyltin was prepared by exposing bacterial biofilms to seawater containing either 0.071 or 20.0 ng of tributlytin/mL. Chemical analysis was preformed to quantify the amount of tributyltin that was concentrated on the biofilms. The authors found that dissolved tryibutyltin below 5 ng/mL had no impact on larval activity, but a 36 hour exposure at 30 ng/mL caused a 63% reduction in number of oyster larvae swimming normally. Exposure to 50 ng/mL caused almost 100% mortality. In addition, the exposure pathway appeared to impact tributyltin toxicity; dissolved concentrations had no effect but exposure to the same concentrations in a biofilm disrupted the oyster's life cycle. Exposure to tributyltin in a biofilm inhibited natural attachment and metamorphosis of oyster larvae on bottom surfaces. These results demonstrate the importance of biofilms for the ability to concentrate tributyltin. In addition, measurements of dissolved tributyltin concentrations may not be sufficient to predict toxicity in marine environments; biofilm tributyltin concentrations should also be determined. Rigor Score = 4

Lemiere, S., C. Cossu-Leguille, A. Bispo, M. J. Jourdain, M. C. Lanhers, D. Burnel, and P. Vasseur. 2004. Genotoxicity related to transfer of oil spill pollutants from mussels to mammals via food. Environmental Toxicology 19:387-395.

Oil. Lemiere et al. report on an experimental study in which potential genotoxic effects in rats were evaluated following either a 2 or 4 week exposure to PAH contaminated marine mussels (*Mytilus edulis*). Rats were fed mussels that contained either 100 or 500 µg of total PAHs/kg dry weight. Genotoxic effects were assessed in liver, bone marrow, and peripheral blood of the rats. The authors report that DNA damage was observed in the livers of rats fed mussels with the highest PAH dose (500 µg of total PAHs/kg dry weight). The authors conclude that their findings demonstrate the ability of PAHs in mussels to be bioavailable for higher trophic level species at concentrations that could cause detrimental effects. Rigor Score = 4

Long, E. R., D. D. Macdonald, S. L. Smith, and F. D. Calder. 1995. Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19:81-97.

Discharges. Long et al. assimilate existing laboratory, modeling, and field study data on effects from contaminated marine and estuarine sediments. They determined two gudieline values (effects range-low and effects range-median) for nine trace metals, total PCBs, two pesticides, and 13 PAHs. The two guideline values defined concentration ranges that were 1) rarely, 2) occassionally, or 3) frequently associated with adverse effects. Included in this paper are data tables compiled from serveral studies examining contamiant levels in sediment and adverse biological effects. The authors state that their proposed approach povides reliable guidelines for use in sediment quality assessment. As such, these guidelines may prove beneficial for assessment of sediment toxicty in Glacier Bay. Rigor Score = 2

Luckenbach, T., and D. Epel. 2005. Nitromusk and polycyclic musk compounds as long-term inhibitors of cellular xenobiotic defense systems mediated by multidrug transporters. Environmental Health Perspectives 113:17-24.

Discharges. Luckenbach and Epel demonstrate how nitromusk and polycyclic musk compounds, widely used in personal care products such as detergents and cosmetics, inhibit the activity of multidrug efflux transporters in the gills of marine mussels (*Mytilus californianus*). These transporters are important for excluding toxic compounds out of the cell, so transporter inhibition can cause an accumulation of unwanted intracellular contaminants that may result in altered cell function and/or cell death. One unexpected finding was that a 2-hour exposure of these musk compounds appeared to cause a long-term (24- or 48-hour) loss of transporter activity. Luckenback and Epel also determined that the inhibitory effects of these musk

compounds was additive. The additive effects are a significant finding because combinations of these compounds are used in fragrances, etc., and thus environmental exposures to these compounds usually occur as complex mixtures. This study is relevant in that they describe the mechanism with which personal care products can impact marine species. Multidrug efflux transporters are found across a wide range of taxa, thus concern is warranted for the release of nitromusk and polycyclic musk compounds into Glacier Bay. Rigor Score = 4

Morcillo, Y., and C. Porte. 1998. Monitoring of organotin compounds and their effects in marine molluscs. Trac-Trends in Analytical Chemistry 17:109-116.

Anti-fouling agents. The authors present data on organotin body burden measurements in marine mussels (*Mytilus galloprovincialis)* and the gastropod *Bolinus brandaris*. For *Bolinus brandaris*, imposex (the development of male sex organ characteristics in females) was also assessed. In addition, results from laboratory experiments evaluating tributyltin's impact on mussel enzyme function are reported. Marine mussels and *Bolinus brandaris* were collected from three harbors along the Catalan Coast of the Western Mediterranean. Morcillo and Porte conducted in vitro (in culture, exposing mussel tissue) and in vivo (exposing live mussels) studies to understand tributyltin's effect on mussel enzyme function. In vitro studies used microsomal fractions isolated from the digestive glad in mussels and exposed these fractions for 20 minutes to either 0, 0.1, or 1 mM tributyltin. In vitro exposure to tributyltin did appear to impact enzyme function as demonstrated by a significant decrease in the total metabolic rate of testosterone (28-40%). In vivo studies were carried out by exposing mussels to varying concentrations (91, 454, 2268 ng/L) of tributyltin in seawater. The authors report no significant impact of in vivo exposure on mussel enzyme function, but small changes were observed. Finally, and perhaps most importantly, this paper reports that imposex was found in all the locations sampled, with five out of six having 100% incidence of imposex while the sixth had 37%. These results demonstrate elevated levels of tributyltin in marine organisms and that imposex is still prevalent in *Bolinus brandaris*. Rigor Score = 4

Pedersen, J. A., M. Soliman, and I. H. Suffet. 2005. Human pharmaceuticals, hormones, and personal care product ingredients in runoff from agricultural fields irrigated with treated wastewater. Journal of Agricultural and Food Chemistry 53:1625-1632.

Discharges. Penderson et al. report the incidence of human pharmaceuticals, hormones, and personal care products in treated wastewater. The objective of this study was to determine whether compounds indicative of treated effluent were detectable in agricultural runoff. Surface runoff samples collected from effluent-treated fields in southern California were analyzed using a broad-spectrum gas chromatography-mass spectrometer (GC-MS). The authors' findings are relevant to cruise ship discharge in Glacier Bay because this study provides evidence for the existence of pharmaceuticals, hormones, and personal care product ingredients in treated effluent. Based on these observations, the possibility arises that treated discharges from cruise ships may also contain these potentially harmful compounds. Rigor Score = 1

Peterson, C. H., S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E. Ballachey, and D. B. Irons. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. Science 302:2082-2086.

Oil. Peterson et al. discuss the evidence for long-term ecosystem effects from the Exxon Valdez oil spill. They describe how in the Alaskan coastal ecosystem, unexpected persistence of toxic subsurface oil and chronic exposures, even at sublethal levels, has continued to affect wildlife. Studies evaluating population impacts are summarized for sediment-affiliated species (fish, sea otters, sea ducks) as well as pink salmon. In addition, potential indirect effects of the oil spill are also described. Peterson and coauthors present strong evidence for long-term ecosystem-wide impacts from the Exxon Valdez oil spill. These impacts are important to take into account when assessing the potential consequences of an oil spill in Glacier Bay. Rigor Score = R

Reed, M. D., A. P. Gigliotti, J. D. McDonald, J. C. Seagrave, S. K. Seilkop, and J. L. Mauderly. 2004. Health effects of subchronic exposure to environmental levels of diesel exhaust. Inhalation Toxicology 16:177-193.

Emissions. Reed et al. use a dose-response approach in rats and mice to examine health effects following sublethal exposures to environmental levels of diesel exhaust. The exposures were conducted seven days per week, 6 h/day and included five treatment groups: four dilutions of engine exhaust and clean air (control). Target exposures were set at 30 (low), 100 (mid-low), 300 (mid-high), and 1000 (high) mg/m3 PM. The authors found chronic diesel exhaust exposure in mice and rats resulted in only mild effects for several indicators of general toxicity (organ weight, body weight, hematology parameters, lung volume) and had no effect on two indicators of carcinogenic potential. The study by Harrod et al. (2005), in which reduced bacterial clearance was observed in mice exposed to diesel engine exhaust, is from the same research group as the one presented here. Taken together, results from these two studies indicate that negative health effects from environmental levels of diesel exhaust were not definitively established. Rigor Score = 4

Rimkus, G. G. 1999. Polycyclic musk fragrances in the aquatic environment. Toxicology Letters 111:37-56.

Discharges. Rimkus reviewed studies that document the occurrence and levels of polycyclic musk fragrances in the aquatic environment. Polycyclic musk fragrances are used in almost all scented consumer products (e.g., sunscreen, perfumes, detergents, soaps) with a worldwide production of about 6000 t/year. The properties of different musk compounds are described which could help predict these chemicals' bioaccumulation potential. Rimkus reports concentrations of musk fragrance compounds in sediment (river) and biota such as mussels, shrimp, and fish, which might prove useful for comparative assessment with organisms in Glacier Bay. Rigor Score = R

Saxe, H., and T. Larsen. 2004. Air pollution from ships in three Danish ports. Atmospheric Environment 38:4057-4067.

Emissions. Saxe and Larsen use a previously developed model, the operational meteorological air quality model (OML), to calculate the emission of air pollutants from ships in three Danish ports. They determined that nitrogen oxide (NO_x, =NO +NO_2) ship emissions contributed substantially to the overall NO_x pollution in central Copenhagen. They provide a table (Table 1, page 4060) listing energy consumption and emissions for several classes of ships, including cruise liners. Their annual emission estimates (in tons) for 201 cruise ships spending 18 hours at the dock and 0.5 hours maneuvering was 105 NO_x, 2.8 SO_2, and 2.1 total suspended solids. The mean gross tonnage of the cruise liners used for these calculations was 30,000. The estimate of cruise liner annual emission rates may provide some insight into the annual emissions of cruise ships that enter Glacier Bay, as well as an approximation of the increase in air pollution if the number of cruise ship visitations were increased. Rigor Score = 2

Schreurs, R. H. M. M., J. Legler, E. Artola-Garicano, T. L. Sinnige, P. H. Lanser, W. Seinen, and B. van der Burg. 2004. In vitro and in vivo antiestrogenic effects of polycyclic musks in zebrafish. Environmental Science & Technology 38:997-1002.

Discharges. Schreuers et al. report on an experimental study in which they assess the dose-response relationship between polycyclic musk compounds and antiestrogenic effects in zebrafish. The authors find that polycyclic musk compounds exhibited antagonistic effects on zebrafish estrogen receptor functions in vitro (in culture) and in vivo (in live zebrafish). They also present evidence that these musk compounds exhibit approximately a 600-fold bioconcentration factor in fish tissue. Ultimately, this study i) provides evidence for the

mechanism with which musk compounds can act as endocrine disruptors and ii) documents the ability of musk compounds to bioaccumulate and thus potentially biomagnify up food chains. Taken together, these results demonstrate the potential risk of toxic effects from musk compounds to biota in Glacier Bay. Rigor Score = 4

Sekizawa, J., G. Suter, and L. Birnbaum. 2003. Integrated human and ecological risk assessment: A case study of tributyltin and triphenyltin compounds. Human and Ecological Risk Assessment 9:325-342.

Anti-fouling agents. Sutter et al. conduct an integrated and ecological risk assessment for tributyltin and triphenyltin compounds. This is a fairly recent (2003) review of data on organotin exposure levels and effects (both for human and environmental risk). Included in this review are temporal trend data of tributyltin and triphenyltin concentrations in the Tokyo bay area from the years 1987 to 1993, which shows that tributyltin concentrations are highly variable in seawater but appear to be declining slowly in sediments. Tables are also presented which summarize data on toxic organotin levels (chronic, subchronic, lethal and sublethal) to aquatic organisms. The authors conclude that a risk assessment approach that recognizes common pathways of transport, fate, and exposure, as well as common modes of action would be more efficient than several haphazard independent assessments. Rigor Score = 2

Shaw, D. G. 1992. The Exxon-Valdez Oil-Spill - Ecological and Social-Consequences. Environmental Conservation 19:253-258.

Oil. Shaw provides a discussion on the ecological and social consequences of the Exxon Valdez oil spill. Included in this discussion are details about the oil spill, clean-up efforts, ecological impacts, social impacts, and the overall response to the spill. Although an oil spill of the magnitude of the Exxon Valdez is highly unlikely to occur in Glacier Bay, a cruise ship (which can carry a large amount of fuel on board) sinking or running aground could have devestating consequences to the Glacier Bay ecosystem. Rigor Score = R

Shim, W. J., J. R. Oh, S. H. Kahng, J. H. Shim, and S. H. Lee. 1999. Horizontal distribution of butyltins in surface sediments from an enclosed bay system, Korea. Environmental Pollution 106:351-357.

Anti-fouling agents. Shim et al. report on the sediment horizontal distribution of butyltins in an enclosed bay system in Korea. Butyltin compounds (tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT)) were measured in surface sediment samples (n = 59 stations) throughout the bay. Sediment samples (~the top 2 cm) were collected at about 1.5 to 4 km intervals in January 1995. TBT concentrations ranged from 4 to 382 ng/g as tin on a dry weight basis, and total butyltin concentrations, from 27 to 1763 ng/g. The authors found that elevated concentrations of butyltins were located near sources areas (e.g., harbors and shipyards) while relatively low butyltin concentrations (<250ng/g) were measured far from these source areas. This study presents data from multiple stations located throughout a bay in Japan; the values reported here could prove useful for reference if sediment samples were evaluated for butyltin concentrations in Glacier Bay. Rigor Score = 2

Suter, G. W., T. Vermeire, W. R. Munns, and J. Sekizawa. 2003. Framework for the integration of health and ecological risk assessment. Human and Ecological Risk Assessment 9:281-301.

General. Suter and coauthors present the framework for human and ecological risk assessment developed from a workshop (in 2001) with an international working group for the World Health Organization. They define the term integrated risk assessment as a "science-based approach that combines the processes of risk estimation for humans, biota, and natural resources in one assessment". Included are discussions of how this approach can be applied to a wide variety of assessments that (1) predict the effects of proposed actions, (2) estimate the ongoing

effects of past actions, (3) predict risk of actions at particular places, and (4) estimate risk of hazardous agents independent of location. The proposed framework could prove valuable for establishing risk assessment parameters in order to determine if cruise ship contamination is negatively impacting marine life in Glacier Bay. Rigor Score = R

Terlizzi, A., A. L. Delos, F. Garaventa, M. Faimali, and S. Geraci. 2004. Limited effectiveness of marine protected areas: imposex in *Hexaplex trunculus* (*Gastropoda, Muricidae*) populations from Italian marine reserves. Marine Pollution Bulletin 48:188-192.

Anti-fouling agents. The goal of this study was to evaluate the current impact of tributyltin inside designated Italian Marine Protected Areas (MPAs). Because the occurrence of imposex (development of male sex organ characteristics in females) in marine gastropods is strongly associated with tributyltin exposure, Terlizzi et al. measured imposex in the marine gastropod, *Hexaplex trunculus* to assess tributyltin toxicity. Approximately 40 adult *H. trunculus* specimens were collected from 13 Italian MPAs at a depth ranging from 2 to 10 meters. Two indices were calculated to score the occurrence of imposex in the females: 1) the relative penis size index (RPSI) defined by the formula (mean female penis length)^3/(mean male penis length)^{3}x100; and 2) the vas deferens sequence index (VDSI), i.e. the mean score of stages of imposex development in females as defined by stages 0 to 6, with stage 0 showing no sign of sexual abnormalities and stage 6 being sterile with an absent vulva. The authors found evidence of imposex in all the populations evaluated, and concluded that imposex was still evident along the coast of Italy, more than 10 years after governmental restrictions on tributyltin use. Of relevance to contaminant impacts in Glacier Bay, imposex was documented in relatively pristine areas (Italian MPAs), distant from known localized point sources such as marinas or harbors. Rigor Score = 1

Relevancy Table for Annotated References – Contaminants

Study	Research type	Contaminant[1]	Common Species	Location	Vessel Behavior	Vessel Type	Rigor Score*
Discharges							
Balk and Ford 1999	Lab-based	No: musk compounds	No: algae, minnows, sunfish	NA	NA	NA	2
Bruchet et al. 2002	Lab based	No: musks, drugs	NA	NA	NA	NA	1
Daughton 2004	Review	No: musks, drugs	NA	NA	NA	NA	R
Hallegraeff and Bolch 1991	Field-based	No: ballast water introductions	NA	No: Australia	NA	No: cargo	2
Kolpin et al. 2002	Field-based	No: drugs, hormones	NA	No: U.S. streams	NA	NA	1
Long et al. 1995	Lab/field-based	No: metals, PCBs, PAHs	Yes: multiple benthic	No: CA, WA, SC, Canada	NA	NA	2
Luckenbach and Epel 2005	Lab-based	No: musks	Yes: mussels	NA	NA	NA	4
Pedersen et al. 2005	Field-based	No: wastewater	NA	No: CA	NA	NA	1

[1] Assume zero discharge of gray/treated black water and oil within Glacier Bay National Park

Study	Research type	Contaminant[2]	Common Species	Location	Vessel Behavior	Vessel Type	Rigor Score*
Rimkus 1999	Review	No: musks	Yes: mussels	No: rivers, North Sea	NA	NA	R
Schreurs et al. 2004	Lab-based	No: musks	No: zebrafish	NA	NA	NA	4
Anti-Fouling Agents							
Alzieu 1998	Review	Yes: tributyltin	Yes: mollusks	NA	NA	NA	R
Beaumont and Newman 1986	Lab-based	Yes: tributyltin	Yes: marine algae	NA	NA	NA	4
Bhosle et al. 2004	Field/lab-based	Yes: butyltin	Yes: mussels	No: India	NA	NA	3
Fent 1996	Review	Yes: organotin	Yes: multiple species	NA	NA	NA	R
Hall et al. 1999	Model-based	Yes: algaecide	Yes: algae	NA	NA	NA	2
Kannan et al. 1998	Field-based	Yes: butyltin	Yes: sea otters	No: CA	NA	NA	3
Katranitsas et al. 2003	Lab-based	Yes: copper-antifouling agent	No: brine shrimp	NA	NA	NA	4
Labare et al. 1997	Lab-based	Yes: tributyltin	No: oyster	NA	NA	NA	4
Morcillo and Porte 1998	Field-based	Yes: organotin	Yes: mussels	No: Europe	NA	NA	4
Sekizawa et al. 2003	Lab/field-based	Yes: organotin	Yes: multiple incl. gastropods	No: Tokyo Bay	NA	NA	2
Shim et al. 1999	Field-based	Yes: butyltins	NA	No: Korea	NA	NA	3

** Rigor Score is an index of study design rigor, using a scale of 1(very rigorous) to 4(observational), as defined by Hill et al. 1997.

[2] Assume zero discharge of gray/treated black water and oil within Glacier Bay National Park

Appendix C:

Potential Impacts of Cruise Ships on the Marine Mammals of Glacier Bay

Potential Impacts of Cruise Ships on the Marine Mammals of Glacier Bay

Literature Review Prepared for the
Glacier Bay National Park and Preserve
Vessel Management Science Advisory Board

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General Considerations

Very little data are available to accurately assess the impacts from cruiseships on marine mammals. Most papers discussing vessel disturbance refer to smaller whale-watching vessels or industrial ships, neither of which typifies the 'behavior' of cruise ships. A further confounding issue is that disturbance effects (e.g. local site movements) and disturbance impacts (where a population is affected) are often confused (Hill *et al.* 1997). Most of the available research published on ship disturbance to marine mammals has focused on short-term disturbance effects rather than longer-term disturbance impacts. Therefore, assessing the impacts of cruise ship disturbance to marine mammals is challenging. However, when evaluating the existing research, the following general patterns do emerge:

1) Marine mammals are typically affected by vessel presence in some manner.
2) Marine mammals are affected by anthropogenic noise even in the absence of vessels (playbacks).
3) Marine mammals vary widely in their reactions to disturbance even among the same species.

Critical gaps in knowledge, and prioritization of suggested research

Currently there is limited, if any, data available to understand the impacts of cruiseships to marine mammals. Research prioritizations include:

1) Use of controlled experiments (presence and absence of cruise ships) with a focus on respiratory behavior of marine mammals to elucidate bioenergetic processes and behavioral responses.
2) Obtain baseline data of stress levels and responses of marine mammals.
3) Determine the radii of audibility and responsiveness (Richardson and Würsig, 1996) for different marine mammals.
4) Use of individual- and population-based models to derive ship-strike probabilities and the potential demographic impacts due to stress and other factors.

5) Quantification of the habituation or sensitization of individual marine mammals to cruise ship presence.

Summary of Impacts by Category

A. General Disturbance (these papers did not distinguish between sound, visual, or physical disturbance)

Factors such as species, age, gender, reproductive condition, and degree of habituation may influence, either singly or in combination, how individual animals respond to anthropogenic activity (Bejder and Samuels, 2003). The following are some of the potential problems that may be caused by disturbance: displacement from important feeding areas; disruption of feeding; disruption of nursing, mating and reproductive and other social behaviors; abandonment of preferred breeding or calving sites; changes to regular migratory pathways to avoid human interaction zones; stress; injury; increased mortality (Australia and New Zealand Environment and Conservation Council, 2000).

i) behavioral impacts

Numerous studies have documented changes in marine mammal behavior in the presence of ships. Typically these behavior changes have been described as avoidance reactions and alarm/startle responses. Responses include increased alertness and temporarily abandoning haul-outs in the case of pinnipeds; and changes in swimming speeds, respiration rates, and direction of travel (usually away from the vessel) for cetaceans.

ii) physiological impacts

Besides potential mortality from ships, no studies conclusively demonstrated physiological impacts from general ship disturbance to marine mammals. However, changes in respiration, swim speed and behavior states (resting to travel, for example) have the potential for longer-term physiological consequences.

Behavior changes in response to ship disturbance can also potentially impact animals in subtle ways. Energy used for an avoidance reaction takes away from energy available for food provisioning, care of young, disease resistance, etc.. Gill *et al.* (1996) discuss how animals are faced with a trade-off between resource use and risk of disturbance and that these trade-offs can be quantified by measuring the amount of resources not used under disturbed conditions.

iii) demographic impacts

Few papers have provided evidence of demographic impacts on marine mammals. The most obvious example of direct demographic impacts on marine mammals is the direct mortality of marine mammals caused by ship strikes. In southeastern Alaska a dead humpback whale was documented in Park waters with injuries consistent with a collision with a large ship (Doherty and Gabriele 2001). Outside the study area, two humpbacks were reported to be struck by vessels in 2003. An adult female humpback died after

being struck by a large ship and was found floating near Yakutat. Another humpback was struck by a cruise ship transiting south of Sitka but the fate of the animal is unknown (Doherty and Gabriele, 2003). The high proportion of calves and juveniles among stranded ship-struck right whales and humpback whales indicates that young animals may be more vulnerable to being hit by ships (Laist *et al*., 2001) which could have further demographic implications.

B. Sound/Vibrations

It is possible that increased levels of underwater noise could be affecting cetaceans in a number of ways such as interfering with their ability to detect biologically important sounds, disturbing their behavior and impairing their hearing sensitivity (Gordon and Moscrop, 1996)**.**

More data on assessments of hearing characteristics such as absolute sensitivity, masking, temporary threshold shifts, and temporal integration, and on the evaluation of behavior during exposure needs to be acquired (National Research Council, 2005).

i) behavioral impacts

Although there are many documented, clearly discernable responses of marine mammals to anthropogenic sound, reactions are typically subtle, consisting of shorter surfacings, shorter dives, fewer blows per surfacing, longer intervals between blows, ceasing or increasing vocalizations, shortening or lengthening duration of vocalizations, and changing frequency or intensity of vocalizations (National Research Council, 2005).

ii) physiological impacts

A few studies have evaluated the possibility of physiological impacts to marine mammals as a result of anthropogenic sound. Thomas *et al.* (1990) assayed levels of blood catecholamine before and after playbacks of an oil drilling platform as a measure of stress in captive belugas. The authors could not detect any short-term behavioral or physiological effects of drilling noise playbacks on the captive belugas. Todd *et al.* (1996), however, noted that orientation ability and ear integrity (structural damage) were both affected by underwater explosions that were characterized by high-energy signatures with principal energies under 1 kHz. Kastak *et al.* (1999) showed that noise of moderate intensity (of 65-75 dB) and duration is sufficient to induce a TTS (temporary threshold shift) under water in three pinniped species (1 harbor seal, 2 California sea lions and one northern elephant seal).

iii) demographic impacts

No studies were able to conclusively link demographic impacts to anthropogenic noise although several suggested that noise may be a factor in distributional shifts in marine mammals.

Summary of Impacts to Marine Mammals

Very little is known about cruise ship disturbance and its potential impacts to marine mammals. Marine mammals are known to often be affected by vessel presence, behavior, and noise. This is most evident in the subtle behavioral changes that are witnessed in marine mammals in a variety of ways. However, as the National Research Council (2005) points out, it remains unknown when and how these changes translate into biologically significant effects at either the individual or the population level. Furthermore, physiological reactions such as elevated heart rate or other manifestations of "stress" may occur even if no overt behavioral response is evident. Therefore, observational data on surfacing, respiration, and dive variables may be useful indirect indicators of physiological state (Richardson and Malme 1993).

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Richardson W.J. & Malme C.I. 1993. Man-made noise and behavioral responses. In: (eds. Burns J.J., Montague J.J. & Cowles C.J.), pp. 631-700. The Society for Marine Mammalogy, Lawrence, KS.

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Todd S., Stevick P., Lien J., Marques F. & Ketten D. 1996. Behavioral effects of exposure to underwater explosions in humpback whales (*Megaptera novaeangliae*). *Can. J. Zool.* 74, 1661-1672.

Annotated References Reviewed in Literature Search

Acevedo A. (1991) Interactions between boats and bottlenose dolphins, *Tursiops truncatus*, in the entrance to Ensenada De La Paz, Mexico. *Aquatic Mammals* 17, 120-124
Abstract: The author continuously recorded dolphin behavior and their reaction to boats. Dolphin reaction was related to boat approach. Dolphins did not modify their behavior when boats cruised between 5 to 25m of them. They dived and resumed their previous behavior when boats cruised within 5m of them. Dolphins modified their behavior when boats followed them. Boats driving through the area did not alter dolphin behavior. Boat traffic also did not alter the frequency of occurrence, location, behavior, and movements of dolphins. The size and shape of the area does not provide a region free of boats. Although small sample size does not allow a conclusive statement, boats that followed dolphins affected their behavior, at least during the time that the dolphins were being followed.

Akamatsu, T., Hatakeyama Y. & Takatsu N. (1993) Effects of pulse sounds on escape behavior of false killer whales. *Nippon Suisan Gakkaishi* 59, 1297-1303
Abstract: Whales were kept in a net enclosure and subjected to different sounds. The behavior of whales after the sounds were transmitted was divided into three categories: "effective", "somewhat effective" and "not effective". Effective behavior indicates that the whales swam directly away from the source of the sound soon after transmission (sound was effective at repelling the animal). The level for the effective category seemed to cluster around 170 dB in the early experiments. The effective thresholds by stable pulses seem to increase in direct ratio to the number of experiments. This seems to indicate a pattern of acclimation in the whales. On the other hand, modulated sound seems to be difficult to acclimate to, since its effective threshold varied little from one experiment to the other. This suggests that complex sounds (modulated or mixed) are harder to acclimate to than stable sounds.

Akamatsu T., Nakamura K., Nitto H. & Watabe M. (1996) Effects of underwater sounds on escape behavior of Steller sea lions. *Fisheries Science* 62, 503-510
Abstract: Captive sea lions were exposed to a variety of sounds to see which was most effective at driving them away. Results suggest that narrow band spectrum sound is more effective in changing the behavior of Steller sea lions than broader band spectrum sound. The sound pressure level is thought to be one of the dominant factors controlling the behavior or Steller sea lions. The 165 dB narrow band signals (pure tone and sweep) seem to be relatively difficult to acclimatize to since the landed number (sea lions hauled out to avoid water noise) was not noticeably affected by the increase in session number. The Steller sea lions can acclimatize to such sound projections and a 165 dB source level is not enough to repel sea lions from fishing nets.

Allen M.C. & Read A.J. (2000) Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. *Marine Mammal Science* 16,
Abstract: Anclote Key was considered relatively pristine and John's Pass site had heavy vessel traffic. Dolphin activity was classified as being foraging or non-foraging. It appears that vessel densities in Anclote Key were not sufficient to evoke a response measurable at our scale of sampling, as habitat preferences were similar for both weekdays and weekends. It is possible that dolphins are habituated to the level of vessel traffic encountered at Anclote key. Alternatively, this study site is large and may provide regions where dolphins are unaffected by vessel traffic. In John's Pass, however, results suggest that dolphins decrease their use of primary foraging habitats during periods of high boat density. Dolphins may shift habitat preferences either directly to avoid areas of high vessel traffic or in response to the response of prey to vessel traffic.

Allen S.G., Ainley D.G., Page G.W. & Ribic A.C. (1984) The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. *Fishery Bulletin* 82, 493-499.
Abstract: Seals responded to disturbances at = 100m more than at distances 101-200 m and 201-300m, and were least reactive to disturbances at 201-300m. After disturbances, the number of seals that eventually rehauled was always lower than the original number. People in non-power boats were the greatest source for disturbance.

Ananthaswamy A. (2004) Beware the ecotourist. *New Scientist* 181, 6-7
Keywords: WHALE WATCHING/ECOTOURISM/MARINE MAMMALS/HUMAN IMPACT ON WILDLIFE
Abstract: Ecotourism is growing 10 to 30 percent per year. When ecotourism is done right, it can work (ex. the carefully controlled tourism of the Galapagos Islands). Researchers are especially concerned about the transmission of diseases to wildlife in Antarctica. The region has seen several unexplained mass deaths of at least a thousand animals each time, including crab eater seals, Adélie penguin chicks and sea lions. Although it is not yet certain that infections carried by humans are to blame, there is reason to be worried.

Anderson I. (1998) With people come plagues: tourists and scientists could be bringing deadly diseases to Antarctica's wildlife. *New Sci.* 159, 4
Keywords: ANTARCTICA/DISEASES/ECOTOURISM/MARINE MAMMALS/PENGUINS/POLLUTION/WILDLIFE DISEASE
Abstract: Tourists and scientists could be bringing deadly diseases to Antarctica's wildlife. A team from Umea University in Sweden has found *Salmonella* and *Campylobacter* bacteria in fecal samples collected since 1996 from Antarctic fur seals, gentoo and macaroni penguins, skuas, and black-browed albatrosses on Bird Island, off South Georgia. In one of the largest outbreaks to date, 1345 New Zealand sea lion pups and 85 adults died from septicaemia on the Auckland islands, 600 km from New Zealand. Biopsies revealed *Salmonella* and a second, unidentified bacterium. Although scientists can't be sure that people are spreading the pathogens, circumstantial evidence suggests that they are. The other main threat is sewage. According to James Smith of Montana Microbiological Services in Bozeman, human feces should be boiled at 100° C for five minutes. The proposals also include procedures for responding to disease outbreaks, to be coordinated by a central agency.

Au D. & Perryman W. (1981) Movement and speed of dolphin schools responding to an approaching ship. *Fishery Bulletin* 80, 371-379
Abstract: Schools usually appeared to be swimming calmly throughout the tracking, until the ship approached to within a mile of the dolphins. Eight dolphin schools (spotted, striped, and spinner) were followed with ship and helicopter. All eight schools continuously adjusted their directions of swimming, by small increments, so that the distance between the school and the ship's

projected track tended to increase continuously with time. It appeared that avoidance behavior sometimes had begun when the school was still 6 or more nm away from the ship. Authors note that ship-avoidance should not be surprising, considering the extent of "porpoise fishing" in the study area.

Au W.W.L., Carder D.A., Penner R.H. & Scronce B.L. (1985) Demonstration of adaptation in beluga whale echolocation signals. *J. Acoust. Soc. Am.* 77, 726-730
Abstract: The ambient noise level in Kaneohe Bay is typically 12-17 dB greater than in San Diego Bay. In San Diego, the animal emitted echolocation signals with peak frequencies between 40 and 60 kHz, and bandwidths between 15 and 25 kHz. In Kaneohe, the whale shifted its signals to peak frequencies between 100 and 120 kHz, and bandwidths between 20 and 40 kHz. It seems that the whale adapted to the higher ambient noise environment of Kaneohe Bay by emitting echolocation signals at frequencies where the ambient noise was relatively low. It is also possible that the whale began to use higher intensity signals in Kaneohe Bay to overcome the effects of the higher ambient noise and that the higher frequencies may be a by-product of the use of higher intensities. The data collected represent the first quantitative evidence of the adaptive capability of a cetacean biosonar system.

Au W.W.L. & Green M. (2000) Acoustic interaction of humpback whales and whale-watching boats. *Marine Environmental Research* 49, 469-481
Keywords: BEHAVIOR/DISTURBANCE/ECOTOURISM/HUMPBACK WHALES/NOISE/WHALE WATCHING/WHALE WATCHING VESSELS
Abstract: Boats were instructed to approach the instrumentation boat and drive in a circle around the measuring boat maintaining a standoff distance of 91m (100 yards) at a speed of 10 knots. Behaviors of focal pods were recorded before, during and after they were approached by vessels to approximately 91 m. The vessel approached the pod at 10 knots, passed by the pod at 91 m and then left the area. Several features of the spectrograms are worth pointing out. The authors concluded that even the noisiest boats in their study would probably not cause any harm to the auditory system of the whales but the ramifications of behavioral changes induced by the presence of boats are open to assessment. Generally, whales appeared to swim fastest in response to the loudest boat.

Australian and New Zealand Environment and Conservation Council. (2000) Australian National Guidelines for cetacean observation and areas of special interest for cetacean observation.
Abstract: The following reactions often, although not always, indicate that a cetacean is disturbed: attempts to leave the area or vessel (quickly or slowly); regular changes in direction or speed of swimming; hasty dives; changes in respiration patterns; increased time spent diving compared to time spent at the surface; changes in acoustic behavior; certain surface behaviors such as tail slashes and trumpet blows. The following are some of the potential problems that may be caused by disturbance: displacement from important feeding areas; disruption of feeding; disruption of nursing, mating and reproductive and other social behaviors; abandonment of preferred breeding or calving sites; changes to regular migratory pathways to avoid human interaction zones; stress; injury; increased mortality.

Bain D.E. & Dalheim M.E. (1994) Effects of Masking Noise on Detection Thresholds of Killer Whales. In: pp. 243-256. Academic Press.
Abstract: This study tested masking on 2 captive killer whales. Masking is the term used to describe any impairment in an animal's ability to detect a signal. Vessel noise is generally strongest directly behind the vessel and is minimal to the front. The whales were sensitive from about 500 Hz (the lowest frequency tested) to over 100 kHz. Critical ratios ranged from 20 dB at 10 kHz to 40 dB at 80 kHz. The increase in critical ratio with frequency is typical of mammals,

so killer whale hearing appears to be impaired in a manner similar to that of terrestrial mammals. Higher levels of noise produced a stronger masking effect. Vessel noise impairs the ability of killer whales to detect low-frequency (up to at least 20 kHz) signals. Since only low-frequency components of killer whale calls are omnidirectional, vessel noise would be expected to impair killer whale communication.

Baker C.S., Herman L.M., Bays B.G. & Bauer G.B. (1983) *Impact of vessel traffic on the behavior of humpback whales in southeast Alaska - 1982 season*. National Marine Fisheries Service, Seattle, WA.
Abstract: Based on data from the study, two vessel avoidance strategies by whales were suggested: (a) horizontal avoidance if vessels were between 2000 to 4000m from the whale; and (b) vertical avoidance if vessels were from 0 to 2000 m from the whales. The horizontal avoidance strategy involved decreased dive times, longer blow intervals, and greater speed of movement. Vertical avoidance involved increased dive times, decreased blow intervals, and decreased whale speeds. Vertical avoidance was the primary strategy observed in response to the Obtrusive vessel interactions 1981. The presence of large ships was significantly correlated with decreased dive times, with increased short pauses (respiratory pauses were the interval between any two sequential blows and short pauses were of less than 3 minutes), and with faster whale speed. The presence of large ships was significantly correlated with the numbers of aerial behaviors. It seems likely that available prey and feeding strategies are an important variable in a complex equation that determines the response of whales to vessel traffic. A coordinated study of whale behavior associated with prey species and availability is strongly recommended.

Baker C.S., Herman L.M., Bays B.G. & Stifel W.S. (1982) *Impact of vessel traffic on the behavior of humpback whales in southeast Alaska*. National Marine Fisheries Service, Seattle, WA.
Abstract: There was a clear and graded effect of the interaction of vessel traffic on the respiratory behavior of whales. The distance of the vessel to the whales was also a significant component of its impact on the respiratory variables. A preliminary assessment suggests that the passage of vessels at distances of less than 900 m causes some disturbance of the whale's respiration. Though the regression calculation is based on a relatively small sample size and is not conditioned by vessel size or speed, it suggests that vessel traffic may have an impact on whales at over twice the minimum distance to whales presently required of vessels in Glacier Bay. In general, the interaction with the experimental vessels resulted in a sharp decrease in blow intervals and an increase in maximum dive time and in total dive time. This effect moderated considerably as the obtrusiveness of the vessel behavior decreased. Recommendations: establish a platform in Glacier Bay, most preferably on the Marble Islands, to collect movement and behavioral data on whale-vessel interactions over a sustained period of observation of approximately 60 days, measure noise levels of traffic in parallel with behavioral observations, continue photo-id and use radio and sonic telemetry to collect protracted observations of the changes in respiration, movement, and depth of dive in response to repeated vessel interactions.

Baker C.S. & Herman L.M. (1989) *Behavioral responses of summering humpback whales to vessel traffic: experimental and opportunistic observations.* U.S. Department of the Interior, Anchorage, AK.
Keywords: BEHAVIORAL RESPONSE/DISTURBANCE/HUMAN INTERACTIONS/HUMPBACK WHALE/SUMMER RANGES/VESSEL TRAFFIC
Abstract: In general, respiratory behavior, particularly blow intervals and dive times, were the most sensitive indicators of disturbance from vessel activity. The behavioral responses of humpback whales to vessel traffic were not uniform with regard to acoustic stimuli. Although the resident whales of Bartlett Cove showed a considerable tolerance for vessel traffic, their

behavioral responses did not suggest true habituation. Vessels within 0.25 nm of whales account for the majority of potential disturbance. In Frederick Sound, 15% of pod movement was devoted to avoiding vessel traffic (within the 4,000m realm of influence) and within 1,000 m this increased to 27%. In Bartlett Cove (considered high-vessel density, whereas Frederick Sound is low-vessel density) measures of vessel activity accounted for a relatively small amount of the variance in respiratory behavior and pod movement.

Barr K. & Slooten E. (1999) *Effects of tourism on dusky dolphins at Kaikoura*. Department of Conservation, Wellington, New Zealand .
Keywords: DUSKY DOLPHIN/ECOTOURISM/NEW ZEALAND/TOURISM IMPACT
Abstract: There was no significant effect on increasing number of boats on dolphin behavior but a larger sample size and longer amount of time without boats is needed to detect behavior changes. The dolphins' response to a combination of commercial boats with fishing and/or private boats suggests that dolphins are sensitive to vessel behavior and uncertainty in vessel behavior. A combination of boats appears to cause the highest level of disturbance. This may be a situation in which it is difficult for the dolphins to predict the behavior of individual boats. Dolphins may be more susceptible to disturbance from early afternoon, as they normally enter a more restful state at that time or they may become less tolerant of boats later in the day in response to continued exposure during the day. Statistical power for detecting differences was low in most cases, partly because of the large amount of time dolphins were accompanied by boats (72% of observation time on average). Case studies suggest that responses were more likely when the dolphin watching regulations were not adhered to. Dolphins have not completely habituated to tourism despite several years of frequent exposure.

Bauer G.B. (1986) The behavior of humpback whales in Hawaii and modifications of behavior induced by human interventions. Honolulu, HI, University of Hawaii at Manoa .
Abstract: There was no significant correlation between numbers of vessels and numbers of humpback whales. It was suggested that this was probably more due to the transitory nature of humpbacks in Hawaii than to a lack of vessel impact. Vessel numbers, speed, proximity, and direction changes were generally associated with higher swimming speeds, higher rates of affiliations, disaffiliations, lateral fluke displays, no-blow rises, blows, and peduncle slaps. These vessel characteristics were also associated with lower rates of flipper extensions and flipper slaps. In general, smaller pods and pods with a calf were more affected than larger pods. The present research indicated significant effects from increases in the number of vessels in the 500 to 1000 m range. The dive times of mother-calf pods increased as proximal vessel numbers increased. The frequency of diving among singletons increased as vessel numbers increased.

Bauer G.B. & Herman L.M. (1986) *Effects of vessel traffic on the behavior of humpback whales in Hawaii*. National Marine Fisheries Service, Honolulu, HI.
Keywords: HAWAII/HUMPBACK WHALE/NOISE/VESSEL TRAFFIC
Abstract: The number of vessels, speed, distance from whales, and changes in direction, all were shown to affect the behavior of whales. Singletons and small groups are affected more than larger groups. The presence of a calf may alter the response characteristics to disturbance. Nonfeeding whales seem more affected than feeding whales. Results indicated that there were significant vessel effects on whale behaviors. The frequency of blows increased with the number of vessels between 500m and 1000m, the proximity of vessels, and the mean change in vessel direction. The frequency of blows decreased when mean vessel speeds increased. Zero-order correlations across all pod types indicated that whales increased their swimming speed and decreased the magnitude of direction change as mean vessel distance from them decreased. The increased respiration rates indicate that singletons in the presence of vessels are aroused and stressed. As proximal vessel numbers increase calves increase their dive time, increase their blow

intervals, and decrease their blow rate per hour. This pattern suggests the possibility that the calf is respiring insufficiently to match its normal rate per hour. Increases in respiration rate, diving behavior, and swimming speed indicate increases in energy expenditure and consequently, increases in stress levels.

Beach D.W. & Weinrich M.T. (1989) Watching the whales: is an educational adventure for humans turning out to be another threat for endangered species? *Oceanus* 32, 85-88
Keywords: 1989
Abstract: The whales of New England have become tolerant of whale-watching and fishing. Even amid the areas heaviest traffic, the humpbacks form large aggregations. By contrast, the humpbacks off southeast Alaska, another important feeding area, appear sensitive to a much lower level of traffic. The southeast Alaska feeding area lies in hard rocky basins that may reflect and/or magnify vessel noise, whereas the open waters and sandy bottom of Stellwagen Bank are more likely to disperse and absorb sound. Also, most of the vessels affecting whales off Alaska are large cruise ships that generate more noise. Regular exposure to passing vessels may, in fact, be the most important component of a population's tolerance of whale watching. Migrating gray whales experience a significant amount of whale-watching at their birthing sites and commercial fishing and shipping traffic all along the west coast and their acceptance of vessel activity appears to be high in spite of the fact that the Soviet Union permits a low level of hunting in the North Pacific. Humpback, gray, and bowhead whales show obvious and universal reactions to certain human intrusions. Investigations in the Arctic Ocean and off Hawaii, California, and Massachusetts found that whales generally avoid approaching boats and low-flying aircraft by increasing their swimming speed, orienting away from the disturbance, and decreasing the amount of time spent at the surface between dives.

Bejder L. & Samuels A. (2003) Evaluating the effects of nature-based tourism on cetaceans. In: *Marine Mammals: fisheries, tourism, and management issues.*, pp. 229-256. CSIRO.
Abstract: Repeated disruption to breeding, social, feeding or resting behavior can have deleterious effects on reproductive success, health, distribution and ranging patterns, or access to preferred habitat. Factors such as species, age, gender, reproductive condition, and degree of habituation may influence, either singly or in combination, how individual animals respond to anthropogenic activity. A focus on individual animals is the preferred method for obtaining unbiased records of behavior. Conducted over time, such studies provide valuable information about the short-term, seasonal, and long-term effects of cetacean-focused tourism on the lives of individual cetaceans, on animals of different gender, age class, activity state, or reproductive condition, and on cetacean communities. Simultaneous recording of multiple response measures appears to optimize the likelihood of response detection. Quantification of the habituation or sensitization of individual cetaceans targeted by tourism should be a priority for impact assessment studies.

Bejder L., Dawson S.M. & Harraway J.A. (1999) Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science* 15, 738-750
Keywords: Hector's Dolphin/Cephalorhynchus Hectori/Eco-Tourism/Impact/New Zealand/Theodolite/Whales
Abstract: Most swim-with-dolphin attempts (57%, n=32) did not appear to disturb the dolphins, as they remained nearby. While our sample size is small, results suggest that at least some interactions cause significant disturbance to the dolphins targeted. Dolphins approached the boat less frequently than expected as encounter duration increased beyond about 70 min. This does not necessarily mean avoidance, as it could also imply that dolphins were showing equivocal behavior towards boats. Nevertheless, it does indicate how long Hector's dolphins in Porpoise Bay were interested in interacting with boats. Dolphins that are forced to spend a great deal of time and energy avoiding boats may end up with reduced biological fitness as a consequence of

the disruption of critical energy budgets. Long-term effects of encounters of longer than 70 min may, for example, reduce breeding success, feeding activity, and resting opportunities. Ultimately, it could cause the displacement of individuals from Porpoise Bay. Dolphins formed significantly tighter pods when the boat was present in the Bay. Tightening of groups is often interpreted as providing increased protection for the individual. Hence it may be that interactions with boats, even if not avoided, might be stressful.

Blane J.M. & Jaakson R. (1994) The impact of ecotourism boats on the St. Lawrence beluga whales. *Environ. Conserv.* 21, 267-268
Keywords: BELUGA WHALE/ECOTOURISM/ECOTOURISM BOATS
Abstract: Out of 367 observations, 21 were statistically significant. The avoidance behavior intensified with the number of boats present. In more than 75% of cases, after a disturbance by a boat, belugas resumed their pre-disturbance behavior. When disrupted, searching and traveling-searching belugas displayed subtle surface avoidance and then resumed their initial activity, whereas feeding and traveling belugas would generally terminate and not resume their activity. The data suggest that there are significant differences in beluga behavior by location-possibly due to variations in site characteristics, such as for feeding. Both avoidance of, and interactions with, boats were positively correlated with boat-speed. Avoidance was negatively correlated with distance from a boat. A change in the angle of approach of a boat resulted in increased avoidance behavior and reduced investigations. The same maneuver by different types of boats did not elicit significant variation in beluga responses. Boats in an area of belugas should decrease their speed and then maintain a constant speed, because belugas tolerate changes in boat speed better than consistent high speeds.

Borggaard D., Lien J. & Stevick P. (1999) Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). *Aquatic Mammals* 25, 149-161
Keywords: CETACEANS/DISTURBANCE/HUMPBACK WHALE/INDUSTRIAL ACTIVITIES /MINKE WHALE/NEWFOUNDLAND/VESSEL TRAFFIC
Abstract: Humpback whales appeared tolerant of transient blasting and frequent vessel traffic, but were more affected by continuous activity from dredging, coupled with vessel traffic. A significant decreased return rate to feeding grounds indicated a possible long-term effect of exposure to blasting. Individually-identified minke whales were resighted in the industrialized area, and appeared tolerant of vessel traffic, but the number of sightings were inadequate to indicate how resight interval was affected. Tracking individually identified animals appeared to provide a more sensitive means of assessing the impacts of industrial activity than did abundance and distribution of populations. Abundance measures may not be an adequate indicator of impact from industrial noise in this study. Photographic resights between 1992-1995 suggest long-term behavioral effects of industrial noise on humpback whales. Todd *et al.* (1996) reports that exposure to blasting at the site in 1992 is related to fishing gear collisions which may reflect orientation disturbances. Further, ear damage was found from some whales that died in fishing gear in lower Trinity Bay in 1992 (Ketten, 1995). The present study provides evidence that these changes in distribution may persist at least across several years.

Born E.W., Riget F.F., Dietz R. & Andriashek D. (1999) Escape responses of hauled out ringed seals (*Phoca hispida*) to aircraft disturbance. *Polar Biology* 21, 171-178.
Abstract: Overall, 6% of the seals escaped as a reaction to the fixed-wing aircraft. The probability of escaping was found to be influenced by the time of day, relative wind direction and wind chill. Overall, about 49% of all seals escaped as a response to the helicopter. During the helicopter surveys wind chill was the only environmental factor found to have an additional effect on the probability of escaping. The study indicated that the risk of scaring ringed seals into the water can be substantially reduced if small-type helicopters do not approach them closer than

about 1500m and small fixed-wing aircraft not closer than about 500m. The probability of escaping was nearly twice as high in the afternoon and about 1.4 times higher when flying with a head wind than with a tail wind. Overall, 50% of the seals entering the water escaped within 400m of the aircraft. The authors suggest that sound was an important factor triggering the escape response particularly in the case of the helicopter where seals were seen to dive up to about 1.5 km away.

Bowles A.E., Smultea M., Wursig B., DeMaster P. & Palka D. (1994) Abundance of marine mammals exposed to transmissions from Heard Island Feasibility Test. *J. Acoust. Soc. Am.* 96, 2469-2484

Bowles A.E., Smultea M., Würsig B., DeMaster D.P. & Palka D. (1994) Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test. *Journal of the Acoustic Society of America.* 96, 2469-2484
Abstract: The results of studies are consistent with anecdotal accounts that whales abandon areas with heavy and uncontrolled vessel traffic. However, no previous study has shown that noise, in the absence of vessel traffic, can produce a similar effect over a wide area. The results reported herein suggest that sperm whales, pilot whales, beaked whales, and minke whales could have altered their distribution in the immediate vicinity of the HIFT transmissions, but that they returned or were replaced by new individuals quickly when transmissions stopped. Unfortunately, insufficient samples were collected to detect changes statistically, or to determine whether or not there were long-term effects of the transmissions. Marine mammals might have been affected by the source transmissions indirectly as a result of effects on their prey species.

Buckingham C.A., Lefebvre L.W., Schaefer J.M. & Kochman H.I. (1999) Manatee Response to Boating Activity in a Thermal Refuge. *Wildlife Society Bulletin* 27, 514-522
Keywords: Boat/Florida/Manatee/Recreation/Refuge/Sanctuary/Temperature/Trichechus Manatus/Trichechus-Manatus/Florida
Abstract: This study showed that manatees continued to use South Bay as a thermal refuge, regardless of the number of boats present. The observed level of boating activity did not appear to drive manatees into colder water farther downstream. The number of boats did, however, have a measurable effect on manatee distribution within South Bay. The proportion of manatees that preferred the sanctuaries increased as water temperature declined and number of boats outside the sanctuaries increased. The study demonstrates that manatees in Kings Bay are more likely to exhibit avoidance of boats as boats numbers increase.

Buckstaff K.C. (2004) Effects of Watercraft Noise on the Acoustic Behavior of Bottlenose Dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science* 20, 709-725
Keywords: Bottlenose Dolphin/Tursiops Truncatus/Acoustic Communication/Whistles/Disturbance Response/Watercraft/Received Level/Conservation/White-Tailed Deer/Signature Whistles/Delphinapterus-Leucas/Playback Experiments/Sampling Methods/Marine Mammals/Boat/Whales/Snowmobiles/Thresholds
Abstract: This resident community of dolphins is exposed to a vessel passing within 100 m approximately every six minutes during daylight hours. The duration and frequency range of signature whistles did not change significantly relative to vessel approaches. However, dolphins whistled significantly more often at the onset of approaches compared to during and after vessel approaches. Whistle rate was also significantly greater at the onset of a vessel approach than when no vessels were present. Increased whistle repetition as watercraft approach may simply reflect heightened arousal, an increased motivation for animals to come closer together, or an effective way to compensate for signal masking, maintaining communication in a noisy environment. Habitat was also a significant factor. Overall, signature whistle frequency range

increased and minimum frequency was significantly lower as a result of differences between shallow and deeper habitat types. The main finding from this study proves that bottlenose dolphins in Sarasota Bay increased their whistle rate on approach, and it is also known that they swim in tighter groups during approaches, much like a social defense response to predation.

Burgess W.C., Tyack P.L., Le Boeuf B.J. & Costa D.P. (1998) A programmable acoustic recording tag and first results from free-ranging northern elephant seals. *Deep Sea Research II* 45, 1327-1351.
Abstract: The results of this study demonstrate that hydrophone tags can assess subjects' production and reception of low-frequency sound, measure potential interference from anthropogenic sources, and detect basic behavioral responses. Moreover, we find that the tags can acoustically measure swim stroke, respiration, and cardiac function, and can even obtain position information from ranging beacons. The flexibility of a programmable tag could allow it to postpone sampling until normal behavior resumes, either by waiting a specified period or by monitoring the behavior itself for a return to baseline. Our results suggest that CAP technology may increase our knowledge of animal behavior and physiology in the wild, while decreasing the logistic constraints, costs, and potential disruption associated with study vessels.

Calambokidis J., Steiger G.H., Evenson J.R. & Jeffries S.J. (1990) Censuses and disturbance of harbor seals at Woodward Bay and recommendations for protection. Cascadia Research Collective.
Abstract: Significantly more seals tended to use the site on weekdays than on weekends. This pattern was not the case prior to 1984. This pattern is likely reflective of the increase in disturbance by pleasure boaters at the site on weekends. The frequency of disturbance was almost twice as high on weekends. Curiosity of boaters was the primary activity that caused any type of disturbance in the seals. Harbor seals are considered the most wary of the pinnipeds as an instinctive reaction from hunting and land predators. Kayaks tended to disturb more seals than any other type of disturbance. Recommendations: posting of signs, informational brochure, newspaper article, NMFS enforcement, designated area for seals where no people are allowed, a clearly marked barrier that prevents boaters and people on foot from approaching closer than 100 m, training of personnel at site. Also, activities that are disruptive to seals are best conducted in early morning hours and during rainy days because use of the site generally increases through the day and is highest when there is no precipitation.

Cassini M.H. (2001) Behavioural Responses of South American Fur Seals to Approach by Tourists - a Brief Report. *Applied Animal Behaviour Science* 71, 341-346
Keywords: Seal/Arctocephalus Australis/Tourism/Marine Mammals
Abstract: The author studied responses at a non-reproductive, continental colony in Uruguay, which was a resting site for juveniles, subadults and adult males. Fur seals tolerated relatively close distances to humans, but a strong response of the animals was elicited when tourists crossed the threshold of 10m. Calm people (quiet and still) were able to approach the colony without almost any disturbance whereas a very strong response was the reaction to _'intense behavior' (loud, running, moving hands). These results suggest that with a minimum of control on visitor's behavior, the impact of tourism on this colony would be low. The most common type of response of fur seals was partial retreats, although the occurrence of animals leaving the rookery was relatively frequent. The best strategy for reducing the disturbance of ecotourism is to control the distance of approaches and to offer some guidance on the attitude of people during tourist visits.

Cessford G.R. & Dingwall P.R. (1999) An approach to assessing the environmental impacts of tourism. New Zealand Department of Conservation, Wellington, New Zealand.
Keywords: ECOTOURISM/ENVIRONMENTAL IMPACT/TOURISM IMPACT

Abstract: Ideally, for any given category of conservation value, the relevant baseline research and information resource of knowledge should already have established the following: what values are most important; what the main impact vulnerabilities are, and what the key sites in their disturbance are. Systematic approaches need to be developed for identifying and prioritizing key conservation values. These would cover the species, ecosystems, associations, or physical features of greatest conservation importance. Making use of spatial database and analysis systems (e.g. GIS) to integrate spatial information for different conservation values is essential for any approach to systematically identify site-specific visitor impact issues. This will be based on identifying the high priority sites for the high-priority conservation values. Then it is possible to overlay visitor use to identify visitor impact hot-spots and then possible management actions become more clear. The priority conservation value should be clearly known and located; the visitor/value _'hot-spot' identified and defined; and the appropriate site-specific management action identified.

Cessford G. & Dingwall P.R. (1998) Research on shipborne tourism to the Ross Sea region and the New Zealand sub-Antarctic islands. *Polar Rec.* 34, 99-106
Abstract: Results from questions are intended to inform managers how visitors perceive their own impacts, what impact issues may be important at specific sites, and how they perceive possible management actions required to minimize these impacts. Trampling of plants and/or soils (36%) and wildlife disturbance (33%) were the impacts most often cited. Wildlife disturbance comprised people approaching birds and seals too closely, thus causing the animals to retreat or react aggressively. The response reflects the proximity of the landing site to large numbers of Hooker's sea lions, which often exhibit aggressive challenge behavior to people. There was a general preference for more information about any research being carried out at sites, and for improved use of signs and written material as information sources. The responses summarized reinforce the general conclusion that the tourists strongly support most of the management restrictions on visits.

Clapham P.J. & Mattila D.K. (1993) Reactions of humpback whales to skin biopsy sampling on a West Indies breeding ground. *Mar. Mammal Sci.* 9, 382-391
Keywords: 93NOV/HUMPBACK WHALE/REPRINT FILE/SKIN BIOPSY/SKIN BIOPSY SAMPLING
Abstract: Evasive behavior related to vessel approach was exhibited prior to 72 (12.0%) of 598 hits and 100 (24.1%) of 415 misses. Authors were unable to allocate time to a standardized control period prior to vessel approach, but did note behavior before and after a shot to identify behavior changes. An evasive behavior is defined as that in which the animal actively attempted to move away from the vessel, or exhibited decreased surface time, or both. For all classes except competitive groups, the manner in which a vessel approaches a group of whales has a major influence on the probability that a negative response will be elicited. Again, this proved to be particularly true with mother/calf pairs. We experimented with many different approaches during this study, and it was clear that a slow, patient approach to groups (including those containing a calf) produced less evasion and yielded a higher probability of sampling success than more aggressive techniques. While individual variation guarantees that some whales will be unapproachable no matter how careful the boat driver, most whales (even mothers) seem to habituate to the presence of a vessel given sufficient time.

Constantine R., Brunton D.H. & Dennis T. (2004) Dolphin-Watching Tour Boats Change Bottlenose Dolphin (*Tursiops truncatus*) Behaviour. *Biological Conservation* 117, 299-307
Keywords: Dolphin-Watching/Tourism/Bottlenose Dolphin/Human Disturbance/Whales Orcinus-Orca/Human Disturbance/Sampling Methods/National-Park/New-Zealand/Responses/Population/Coastal/Canada/Bay

Abstract: The present study indicates that the behavior of this isolated population of 400-500 bottlenose dolphins was affected by boat interactions. This varied with season and school size, but in all cases where there were significant differences, the frequencies or duration of resting and milling behaviors, in particular, were different. Behavior was affected by the number of boats present and the type of boat. Their behavior was also affected by an increase in the number of permitted operators and a change in departure times (to staggered times). Because these changes occurred simultaneously it is not known whether one of these factors affected the behavior more than the other or if there was a cumulative effect. The data indicated that the permitted boats had an impact above other boat types (they spend the most time actually with the dolphins). The amount of resting decreased significantly with an increase in the number of boats. Resting behavior was more likely to decrease for smaller schools of dolphins in the presence of boats than for larger schools. The consistent response of dolphins to the presence of permitted boats in the Bay of Islands over the research period suggest that this population, despite frequent contact, have not habituated to these tours.

Corkeron P.J. (1995) Humpback Whales (*Megaptera-Novaeangliae*) in Hervey Bay, Queensland - Behavior and Responses to Whale-Watching Vessels. *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 73, 1290-1299
Keywords: Southern Gulf/West-Indies/Waters/Maine
Abstract: The effects of the presence of vessels on the behaviour of humpback whales (Megaptera novaeangliae) was studied in Hervey Bay, Queensland, where southward-migrating whales are the focus of a commercial whale-watching industry. The behaviour of whales was observed from a small yacht under sail. Rates of occurrence of units of behaviour for entire pods were obtained from continuous sampling of pods. Pods without calves showed lower rates of behaviour generally when vessels were within 300 m of them. Pods both with and without calves were more likely to dive rather than slip underwater when vessels were within 300 m. Hybrid multidimensional scaling of rates of behaviours of pods indicated differences between suites of behaviours exhibited by pods when vessels were within 300 m of them and when they were not. Classification of the patterns of occurrence of behaviours demonstrated that for pods both with and without calves, different units of behaviour tended to occur together when vessels were within 300 m and when they were not. Whale watching offers a nonlethal commercial use of whales, but in Hervey Bay, whale watching affects the behaviour of whales, which, although migrating, can be involved in breeding ground activities. Whether the short-term behavioural changes described here are accompanied by longer term avoidance of Hervey Bay by humpback whales as they migrate south remains to be determined.

Corkeron P.J. (2004) Whale Watching, Iconography, and Marine Conservation. *Conservation Biology* 18, 847-849
Keywords: Fisheries/Behavior/Sea
Abstract: Nature-based tourism does not necessarily maintain environmental quality. Whale watching tends to be classified as ecotourism, but it does affect whales' behavior in the short term (e.g., Corkeron 1995). Research to date demonstrates that anthropogenic noise is primarily responsible for the short-term behavioral changes observed. Management issues for whales and dolphins are very different. Coastal dolphins tend to live in discrete societies with relatively small home ranges; so daily disturbance from tourist vessels becomes habitat degradation. Sustainable populations and minimum viable populations are becoming interchangeable terms in some nations' approaches to managing marine mammals.

Coscarella M.A., Dans S.L., Crespo E.A. & Pedraza S.N. (2003) Potential impact of unregulated dolphin watching activities in Patagonia. Journal of cetacean research and management [J. Cetacean Res. Manag.]. 5[1], 77-84.

Abstract: Feeding is the most affected activity by the approach of the boat for Dusky dolphins. Almost half of the times that the dolphins were found feeding, they changed their behavior. For Commerson's feeding was the behavior that was recorded the least before the boat approached; however, when dolphins were around the boat the relative frequency of feeding increased. The proportion of groups leaping in the vicinity of the boat (50m radius) was significantly higher than the proportion of groups away from the boat (more than 50m) or with no boats in the area. The information presented here suggest that Commerson's dolphins react to the presence of the boat, but once the dolphins are around the drifting boat, they carry out activities that are usually not expected in a stressful situation. This could be interpreted as a sign that the dolphins (at this level of activity) are not severely affected by boats.

Costa D.P., Crocker D.E., Gedamke J., Webb P.M., Houser D.S., Blackwell S.B., Waples D., Hayes S.A. & LeBoeuf B.J. (2003) The effect of a low frequency sound source (ATOC) on the diving behavior of northern elephant seals, *Mirounga angustirostris*. *Journal of the Acoustic Society of America.* 113, 1155-1165
Abstract: In no case did an animal end its dive or show any other obvious change in behavior upon exposure to the ATOC sound. Subtle changes in diving behavior were detected however. The biological significance of these subtle changes is likely to be minimal.

Doherty J.L. & Gabriele C.M. (2002) Population characteristics of humpback whales in Glacier Bay and adjacent waters: 2002. Gustavus, AK, GBNP.
Abstract: The standardized count of 56 whales in Glacier Bay and Icy Strait is the lowest standardized whale count in the study area since 1995. The crude birth rate is 12.9%. It was reported that a cruise ship maneuvered in a circle around at least two humpback whales and appeared to be less than 800 meters (0.5 mile) from shore. A tourist in a sea kayak collided with a humpback whale, causing the kayak to capsize. A 20-meter motor vessel, reported that a whale bumped the vessel's hull while the vessel was anchored in Bartlett Cove (J. Challoner-Wood, pers. comm.). Two whales had injuries that the nature and severity of the damage strongly indicate that they resulted from a collision with a vessel and it is believed that these two individuals are habituated to vessel traffic. Habituation to vessel presence is recognized as one of the main factors contributing to the risk of vessel/whale collisions (Doherty and Gabriele 2001) because habituated whales may ignore approaching vessels. Cruise ships and tour boats may be of particular concern because the larger the vessel, the higher the likelihood that a collision will be fatal to the whale (Laist *et al.* 2001). The threat of collisions in southeastern Alaska is real, as demonstrated in 2001 when we documented a dead humpback whale in Park waters with injuries consistent with a collision with a large ship (Doherty and Gabriele 2001) and in 1999 when a cruise ship struck and apparently killed a humpback whale approximately 100 km south of Juneau (Fry 1999). In both of these incidents, the potential for whale disturbance or collision becomes almost minor in comparison to the possible consequences if the ship ran aground and spilled fuel as a result of maneuvering a large vessel in close proximity to shore. The number of whales in Glacier Bay has decreased each year since 1998, although the numbers of whales in Icy Strait and the entire area have been variable over that time period. Variability on local and regional scales likely demonstrates the whales' changing distribution in response to local conditions, rather than genuine population increases or decreases.

Doherty J.L. & Gabriele C.M. (2001) Population characteristics of humpback whales in Glacier Bay and adjacent waters: 2001. Gustavus, Alaska, Glacier Bay National Park and Preserve.
Abstract: One whale died during the survey season from a ship-strike. Habituation to vessel presence and increasing populations of whales and vessels are two main factors contributing to the high risk of vessel/whale collisions in southeast Alaska. The authors presume that the low whale numbers in Glacier Bay were correlated with a relatively low abundance of whale prey

there compared with other areas. Unfortunately, data on the abundance and distribution of forage fish in Glacier Bay and Icy Strait are not collected annually. Standardized, annual assessments of forage fish temporal and spatial patterns throughout the study are needed in order to understand how these patterns affect whale distribution and abundance, especially in the context of the Park's vessel management policies pertaining to whale waters.

Doherty J.L. & Gabriele C.M. (2003) Results of humpback whale population monitoring in Glacier Bay and adjacent waters: 2003. Gustavus, AK, GBNP.
Abstract: A record number of whales was documented in Glacier Bay and high numbers in Icy Strait as well. The crude birth rate was 6.1%. There were two incidents in GB in which a humpback surfaced in very close proximity to a transiting cruise ship's bow, but neither close call resulted in a collision. The operator of a 6.7 m zodiac struck a single humpback in Icy Strait but both the whale and operator survived. There were 5 incidents in which whales were harassed by aircraft circling or hovering at low altitude. A possible entanglement was reported but not verified. Outside the study area, two humpbacks were reported to be struck by vessels. An adult female humpback died after being struck by a large ship and was found floating near Yakutat. Another humpback was struck by a cruise ship transiting south of Sitka but the fate of the animal is unknown.

Doherty J.L. & Gabriele C.M. (2004) Results of humpback whale population monitoring in Glacier Bay and adjacent waters: 2004. Gustavus, AK, GBNP.
Abstract: Overall the humpback whale population in southeastern Alaska is growing. Between 1979 and 2000, the annual population growth rate in this region was estimated to be 8.8% (Angliss and Lodge 2004. The crude birth rate (11.8%) was typical of previous years. We documented the majority of the mother/calf pairs in Glacier Bay. We are aware of three incidents in Glacier Bay in which humpback whales surfaced in very close proximity to cruise ships, but none of these close calls resulted in a collision (M. Blakeslee, pers. comm., M. Fisher, pers. comm.). On two separate occasions we documented a float plane and a private vessel harassing whales in Glacier Bay. In mid-August at least one, and possibly two, entangled humpback whales were documented in Icy Strait (NMFS Alaska Region stranding database, unpublished data). The number of whale-human interactions that we documented in 2004 was unusually high compared to previous years. The frequency of interactions is likely attributable in part to increases in the overall size of the southeastern Alaska whale population.

Duffus D.A. (1996) The recreational use of grey whales in southern Clayoquot Sound, Canada. *Appl. Geogr.* 16, 179-190
Keywords: BRITISH COLUMBIA/CANADA/GRAY WHALE/WHALE WATCHING

Duffus D.A. & Dearden P. (1993) Recreational use, valuation, and management, of killer whales (Orcinus orca) on Canada's Pacific coast. *Environmental Conservation* 20, 149-156
Keywords: 94JAN/BRITISH COLUMBIA/CANADIAN PACIFIC COAST/KILLER WHALE/MANAGEMENT/REPRINT FILE
Abstract: Alterations to the surrounding ocean ecosystems or wider ecocomplex, will influence the species-habitat relationship and under many conditions could affect whales' affinity for given sites. The dimensions of the harassment issue can be divided into direct, largely behavioral, influences, and indirect ecological consequences. Three levels of potential consequences of disturbance can be classified: immediate, from actions such as whale-vessel collisions; short-term interference with important behavior, and cow-calf pairs, all of which may cause energetic imbalances, reduce foraging success, and interfere with acoustic processes; and long-term reduction of fitness on a local or regional basis through changes in ecological/energetic systems and breeding success. In general, all of the short-term consequences may accumulate into long-

term consequences, and behavioral change may accumulate into ecological and population change.

Edds P.L. & Macfarlane J.A.F. (1987) Occurrence and general behavior of balaenopterid cetaceans summering in the St. Lawrence Estuary, Canada. *Canadian Journal of Zoology* 65, 1363-1376
Abstract: Based on our many hours of observation, we believe the whales must alter their paths to avoid vessels in the St. Lawrence seaway: both whales and ships were frequently abundant off our site, but were rarely in close proximity. In general, whales most frequently changed their angle of travel slightly, or increased the duration and speed of underwater travel to increase the distance between the whale and the vessel. The observations of a single finback pursued by a ferry and the pair of finbacks pursued by a small outboard indicate that finbacks respond to boats at distances of a km or more much the same as do other baleen whales.

Engelhard G.H., Baarspul A.N.J., Broekman M., Creuwels J.C.S. & Reijnders P.J.H. (2002) Human disturbance, nursing behavior, and lactational pup growth in a declining southern elephant seal (*Mirounga leonina*) population. *Canadian Journal of Zoology* 80, 1876-1886
Abstract: Isthmus East and Middle Beach are here considered areas of high and low levels of human presence, respectively. The behavior of elephant seal mother-pup pairs immediately before, during, and after visits to seal harems by field investigators was compared. Most noticeable, presence of people resulted in a significant change in the alertness of elephant seal mothers; frequency of alertness was, on average, raised to a threefold level during human visits. Of the nine variables examined, none was significantly different between seals on Middle Beach and Isthmus East. We provide correlational evidence that during the initial stages of lactation, suckle bouts are a factor limiting the growth rate of the pup. This implies that if disturbance leads to a reduction in average durations of suckle bouts, a negative effect on weaning mass and, hence, probability of survival is also to be expected. We suggest that detailed recordings on suckle bout durations are a more sensitive behavioral indicator than observations on the most conspicuous behavioral responses, such as the levels of alertness.

Erbe C. (2003) Assessment of bioacoustic impact of ships on humpback whales in Glacier Bay, Alaska. Gustavus, Alaska, submitted to, Glacier Bay National Park and Preserve.
Abstract: The results of this modeling exercise should not be used for environmental decision-making. Reaction thresholds will depend on the current behavioral state of the animal; its previous experience with the particular (similar or other) sound (habituation versus sensitization); age, gender and health of the animal; group composition (groups with calves appear more responsive); habitat and geographic location (e.g., close to shore vs. offshore); season and time of day. For humpback whales under typical ambient noise conditions in Glacier Bay, ambient noise is about 20 dB above the upper audiogram and over 40 dB above the lower audiogram at 2-3 kHz. The cruise ship was modeled audible over all depths out to ranges of40km and beyond for both audiogram envelopes. The main energy of the cruise ship spectrum lies at the main frequencies of the humpback _'whup'. A behavioral response was predicted over 10km at depth and beyond 40km range in the sound channel. Given that the frequency band of main energy of the ship noise overlaps with the frequencies of main energy of the humpback _'whup', the zone of masking was large: >40 km range for both audiograms. The zone of behavioral response extended over 10km at depth and beyond 40km range in the near-surface sound channel. It would be advisable to measure transmission loss in the field in Glacier Bay at some stage to confirm the sound propagation results of the current model. In particular for the cruise ship, low frequencies at 80-100Hz had greater impact than higher frequencies. It would be interesting to measure and assess summed noise levels of a number of vessels in the same area and to estimate noise exposure

statistics for humpback whales throughout the year. It is important to point out that ambient noise in Glacier Bay lies well above the lower audiogram envelope.

Erbe C. Underwater noise of whale watching boats and its effects on marine mammals. IWC.
Abstract: The author modeled the acoustic impacts at a SS (sea state) of ″ in Haro Strait (thus modeling a "worst case" scenario). At high speeds, whale watching boats were audible to killer whales over 15 km range and masked a killer whale call over 12 km range. At low speeds, audibility and masking were limited to 1 km range. According to my model, behavioral disturbance should be observed over 200 m from fast boasts and 50 m from slow boats. Quite aside from the danger of collision, whale watching boats should go at low speeds in killer whale habitat where animals can be expected within 850 m, to avoid any impact of serious hearing damage. On various occasion, we observed whales within 50m of stationary or slowly cruising boats. In this case, a small TTS of 4.8 dB could occur after 20 minutes due to one boat. For PTS, animals would have to stay within 50m for hours per day and all through the year, for many years.

Erbe C. (2002) Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. *Marine Mammal Science* 18, 394-418
Keywords: KILLER WHALE/NOISE/UNDERWATER NOISE/VESSEL IMPACT/VESSEL TRAFFIC/WHALE WATCHING
Abstract: Underwater noise of whale-watching boats was recorded in the popular killer whale-watching region of southern British Columbia and northwestern Washington State. A software sound propagation and impact assessment model was applied to estimate zones around whale-watching boats where boat noise was audible to killer whales, where it interfered with their communication, where it caused behavioral avoidance, and where it possibly caused hearing loss. Boat source levels ranged from 145 to 169 dB re 1 muPa @ 1 m, increasing with speed. The noise of fast boats was modeled to be audible to killer whales over 16 km, to mask killer whale calls over 14 km, to elicit a behavioral response over 200 m, and to cause a temporary threshold shift (TTS) in hearing of 5 dB after 30-50 min within 450 m. For boats cruising at slow speeds, the predicted ranges were 1km for audibility and masking, 50 m for behavioral responses, and 20 to for TTS. Superposed noise levels of a number of boats circulating around or following the whales were close to the critical level assumed to cause a permanent hearing loss over prolonged exposure. These data should be useful in developing whale-watching regulations. This study also gave lower estimates of killer whale call source levels of 105-124 dB re 1 muPa.

Evans P.G.H., Canwell P.J. & Lewis E.J. (1992) An experimental study of the effects of pleasure craft noise upon bottlenose dolphins in Cardigan Bay, West Wales. In: *in, European research on cetaceans.* pp. 43-46. European Cetacean Society, Cambridge.
Abstract: Before disturbance by an actual craft, 46% of dolphin orientations were neutral with respect to the subsequent direction of the sound source. On appearance of the vessel, 150-300 meters away, 80% of dolphin orientations were away from the sound source; this subsequently declined to 58% of dolphin orientations. In all cases, dolphins dived in response to the sound source, and then made frequent short dives as they rapidly swam away. The response was greater when the disturbance was repeated in short succession. When sound disturbance occurred in the vicinity of a mother and her calf, the two immediately emitted very rapid high-frequency clicks, presumably for quick location of one another. The reaction of bottle-nosed dolphins to approaching vessel was to make longer dives and move away from the source of the sound. This response occurred over a range of 150-300m at sea states of 3-4, suggesting that these were the threshold distances for an adverse reaction to boats in those conditions.

Findlay K. (1997) *A review of the effects of tourism activities on cetaceans*. International Whaling Commission.
Abstract: Reactions of mammal species to human activities generally fall into one of three categories: lack of observed response, short-term effects, and long-term effects. Lack of observed response could be interpreted in one of three scenarios: the first scenario is that the animals are unaffected by the activity. The second scenario is that the animals have become habituated to the activity. The third scenario is that the whales tolerate the activity despite being physiologically stressed, due to the importance of the region in the ecological or physiological requirements of the animals. Short-term effects are defined here, as those effects which have no permanent or long-term impacts on individuals or the population. Long-term effects include permanent distribution changes or changes in vital population parameters (reproductive rate, recruitment to the breeding population or adult mortality). Such changes might be induced by stress, the disruption of behaviors such as those important to population survival or recovery or displacement of animals from habitats vital to population survival. Cumulative effects of short-term responses may lead to long-term avoidance responses, or to habituation if the activity is non-threatening.

Finley K.J. et al. (1990) Reactions of belugas, (*Delphinapterus leucas*), and narwhals, (*Monodon monoceros*), to ice-breaking ships in the Canadian High Arctic. In: (eds. Smith T.G., St. Aubin D.J. & Geraci J.R.), pp. 97-117. Department of Fisheries and Oceans, Ottawa, Canada.
Keywords: 93OCT/BELUGA/ICE-BREAKING SHIPS/NARWHAL/REPRINT FILE
Abstract: Typically, belugas moved rapidly along ice edges away from approaching ships whereas narwhals showed no overt panic reaction. Presumed alarm vocalizations of belugas indicated that they were aware of an approaching ship over 80 km away and they showed strong avoidance reactions to ships approaching at distances of 35-50 km. Narwhals showed subtle responses to approaching ships. Ship approaches caused narwhals to cease vocalizing temporarily. Belugas and narwhals returned to the disturbance area when nose levels were higher than those to which they initially reacted. This suggests that their initial response were startle responses, and that their sensitivity to ship noise declined subsequently.

Foote A.D., Osborne R.W. & Hoelzel A.R. (2004) Whale-call response to masking boat noise. *Nature* 428, 910
Abstract: We find longer call duration in the presence of boats for all three pods (southern resident killer whales in WA and B. C.). This result indicates that these whales adjust their behavior to compensate for anthropogenic noise once it reaches a threshold level. Recordings were made in the presence or absence of boat noise during three time periods: 1977-81, 1989-92, and 2001-03. We found no significant difference in the duration of primary calls in the presence or absence of boats for the first two periods, but a significant increase (about 15%) in call duration for all three pods in the presence of boats during the 2001-03 period. The average number of vessels attending the whales increased roughly fivefold from 1990 to 2000, suggesting that there is a threshold level of disturbance beyond which _'anti-masking' behavior, such as increased signal duration, begins.

Frankel A.S. & Clark C.W. (2002) ATOC and other factors affecting distribution and abundance of humpback whales (*Megaptera novaeangliae*) off the north shore of Kauai. *Marine Mammal Science* 18, 644-662
Abstract: ATOC did not affect the abundance of whales in the area. The distribution of animals proved to be a more sensitive metric than relative abundance, revealing smaller scale changes. Examination of the mean angles showed that the distribution of whales shifted slightly away from the source location during ATOC blocks. This was supported by the slight (2.6%) increase in mean distance between the source and the whales during the ATOC transmissions. More

animals were found at shorter ranges (<9 km) from the source during ATOC than during the control conditions. The effect on distribution is real, but more complex rather than a simple avoidance response and the magnitude of the effect is small.

Frankel A.S. & Clark C.W. (2000) Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. *J. Acoust. Soc. Am.* 108, 1-8
Abstract: No overt responses to ATOC were observed for received levels of 98-109 dB re 1 Pa. Distance and time between successive surfacings of humpbacks increased slightly with an increase in estimated received ATOC sound level. The results (and compatibility to previous studies) suggest that at least for the ATOC signal, the received sound level is a good predictor of response. There was no effect of ATOC sound level on blow rate; however, the presence of vessels affected the surface blow rate. The parameter estimate indicated a decrease in surface blow rate when vessels were present. Both studies (this and Frankel and Clark, 1998) documented similar responses at similar received levels but at vastly different distances from the source (100-2000 m vs 8-12 km). This indicates that for the ATOC signal, received level proved to be a better predictor of response than proximity.

Frankel A.S. & Clark C.W. (1998) Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, in Hawaii. *Canadian Journal of Zoology* 76, 521-535
Abstract: A comparison revealed no difference in whale tracks and bearings between control and playback conditions. Vessels had a larger impact and affected more behavioral variables than playback. The results indicate that there was a slight trend toward longer dives as a result of playback of M-sequence signals. The responses of other species to broadband noise, and the lack of response of humpback whales to narrowband noise, indicate that the bandwidth of the noise may be an important determinant of marine mammals' responses, probably along with other factors. The lack of response at the 120- dB isopleth in this study supports the interpretation of earlier data (e.g. Malme 1983, 1984) as a response to the vessel itself rather than to the sound level.

Freddy D.J., Bronaugh W.M. & Fowler M.C. (1986) Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildlife Society Bulletin* 14, 63-68
Abstract: Deer exhibited initial high response at greater distances from persons than from snowmobiles. Deer moved greater horizontal distances when initially fleeing from persons than from snowmobiles. Distance at which high response was provoked tended to increase from initial to third trials suggesting sensitization (deer did not habituate). However, deer moved similar horizontal distances during all trials suggesting an upper limit to distance moved. Deer were more disturbed by persons than snowmobile. Responses to persons were longer in duration, involved running more frequently, and were greater in estimated energy expenditure. Intensity of responses was dependent upon distance between animals and disturbances. If human activities were further restricted to trails, deer might perceive the activities as predictable and more acceptable (MacArthur et al. 1982).

Frid A. & Dill L. (2002) Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6,
Abstract: Research on disturbance has begun to embrace the principle that nonlethal disturbance stimuli caused by humans are analogous to predation risk. In the context of our argument, disturbance denotes a deviation in an animal's behavior from patterns occurring without human influences. We use the term disturbance stimulus for a human-related presence or object [e.g., birdwatcher, motorized vehicle] or sound [e.g., seismic blast] that creates a disturbance. The risk-disturbance hypothesis predicts that responses by disturbed animals track short-term changes in

factors characterizing disturbance stimuli, with responses being stronger when perceived risk is greater. Habitat choice is the outcome of decisions that balance the trade-off between predation risk and resource richness. We suggest that the risk-disturbance hypothesis would increase the scope of models by ensuring that underlying mechanisms are considered a priori.

Gabriele C.M. & Doherty J.L. (1998) Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1998. U. S. National Park Service, GBNPP.
Abstract: The crude birth rate of the study population for 1998 is 8.7%. In two observations in Glacier Bay in 1998, whale #1018 reacted to a cruise ship by tail-slapping and trumpet-blowing when a large wake from a cruise ship broke against the shore. One entangled whale was reported in Glacier Bay and Icy Strait. The standardized and total counts of whales in Glacier Bay were also the highest ever, while Icy Strait whale numbers were slightly below average. Whales were observed in predominantly shallow waters, as in previous years.

Gabriele C.M., Doherty J.L. & Andrews A.G.I. (1997) Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1997. U. S. National Park Service, GBNPP.
Abstract: Site fidelity to the study area is high; approximately 70% of the whales identified in a given year have been identified in two or more years in the Glacier Bay/Icy Strait region. The crude birth rate of the study population for 1997 was 10.6%. Seventy-seven (87%) of all calves in the study area have been born to 1 of 16 females that frequent the study area. In Glacier Bay, whale aggregations in high traffic areas such as Bartlett Cove made it difficult for vessels to remain more than ¼ nautical mile from whales as required by Park regulations. No humpback whale entanglements or collisions with vessels were observed or reported in Glacier Bay or Icy Strait in 1997. Bartlett Cove continues to be important whale habitat as well as an area of high vessel traffic concentration.

Gabriele C.M., Doherty J.L. & Lewis T.M. (1999) Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1999. U. S. National Park Service, GBNPP.
Abstract: This year saw the highest number of whales documented in the study area since the monitoring program began in 1985 and it contributes to an increasing trend from 1985 to 1999. The crude birth rate of the study population for 1999, was 8.7%. On 20 August, we observed the cruise ship Veendam approaching within 400 m of the shore and within 100 m of several whales, including one that dove not far off the ship's bow. On July 26 the cruise ship Westerdam struck and apparently killed a humpback whale in Stephens Passage, approximately 100 km south of Juneau. There were no whale strandings, entanglements in fishing gear, or disturbances by aircraft reported in the Glacier Bay/Icy Strait area. Continued monitoring of the distribution of whales throughout the study area is needed to identify what areas are important habitat for whales and to determine whether shifts in distribution (e.g., the heavy use of the area around the Marble Islands or the light of use of the West Arm) are short-term or whether they may warrant changes in the Park's vessel management policies pertaining to whale waters. The increasing local whale population and the array of incidents involving cruise ships, kayaks, and private vessels highlights the need for increased awareness of whale/human interactions in southeastern Alaska.

Gabriele C.M. & Hart T. (2000) Population characteristics of humpback whales in Glacier Bay and adjacent waters. U. S. National Park Service, GBNPP.
Abstract: The crude birth rate of the population in 2000 was 3.4%, a figure which is lower than any crude birth rate observed in this population since 1985. There were no recorded whale/vessel collisions in the study area to the best of our knowledge. There were no whale strandings, entanglements in fishing gear, or disturbances by aircraft reported in the Glacier Bay/Icy Strait area. A systematic study of entanglement scars and other injuries, similar to the work done by

Mattila and Robbins (1998) would greatly advance our knowledge of entanglement and provide an essential basis of comparison to other areas.

Gabriele C.M. & T. M. Lewis. A summary of opportunistic marine mammal sightings in Glacier Bay and Icy Strait 1994-1999.
Abstract: All species, except killer whales and Steller sea lions, tended to be sighted most often in nearshore waters. Most marine mammal sightings occurred in water ranging in temperature from 8-10 C. The number or individual harbor porpoise sighted decreased from 378 in 1996 to 183 in 1999. The greatest drop in numbers of individuals sighted occurred between 1997 and 1998, a 62% decrease. The number of harbor seals sighted declined from 203 in 1996 to 60 in 1999. Similar to harbor porpoise numbers, the greatest decline occurred between 1997 and 1998, a 68% decrease. Our data strongly suggest a decrease in harbor porpoise in the study area. The apparent importance of the Glacier Bay area to both harbor porpoise and harbor seals highlights the need to better understand the population changes that we observed. Vessel disturbance is one of several habitat characteristics that may be a factor in the observed decline in harbor porpoise numbers. Harbor porpoise in Glacier Bay have been observed to avoid motor vessels (Taylor and Dawson 1984). We have no evidence of an increase in the potential sources of harbor porpoise mortality in the study area, nor any data indicating increased harbor porpoise mortality.

Gill J.A., Sutherland W.J. & Watkinson A.R. (1996) A method to quantify the effects of human disturbance on animal populations. *Journal of applied ecology.* 33, 786-792
Abstract: The response to disturbance can be studied in the same way as the response to predation; by measuring the reduction in the use of a resource in response to disturbance. If the animals avoid patches with high disturbance, then, as with the response to the risk of predation, the amount of resource not consumed will be greater in disturbed patches. It is then possible to determine the amount of resources left uneaten as a consequence of disturbance, and the number of animals that could have been sustained by these unexploited resources in the absence of disturbance. In order to use this approach four pieces of information are required: the amount of a given resource in each of a number of patches, the proportion of this resource exploited, the total number of individuals supported by this resource and a measure of disturbance on each patch. The value of this approach is firstly that it clarifies whether or not disturbance is having an effect on the distribution of a population at a given site, and secondly, that it allows quantification of the effect of disturbance in terms of the numbers of animals. In the case of conservation issues this is ultimately the measure which policy-makers require.

Gill J.A., Norris K.E.N. & Sutherland W.J. (2001) Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation* - 97, 265-268
Abstract: The decision of whether or not to move away from disturbed areas will be determined by factors such as the quality of the site currently being occupied, the distance to and quality of other suitable sites, the relative risk of predation or density of competitors in different sites and the investment that an individual has made in a site. Animals with no suitable habitat nearby will be forced to remain despite the disturbance, regardless of whether or not this will affect survival or reproductive success. Traditionally, species showing strong negative relationships would be considered to be those most in need of protection from disturbance. However, the figure shows that this response could in fact be the result of differences in the availability of habitat elsewhere. From a population viewpoint, the species most likely to be adversely affected by disturbances are those for which the fitness costs are high but they have little excess habitat to move to and are thus constrained to stay in disturbed areas and to suffer the costs in terms of reduced survival or reproductive success. For species that feed on mobile or highly aggregated prey, the costs of moving to alternative sites may be great, especially if they are territorial or experience high levels of interference competition.

Glockner-Ferrari D.A. & Ferrari M.J. (1990) Reproduction in the humpback whale (*Megaptera novaengliae*) in Hawaiian waters, 1975-1988: the life history, reproductive rates, and behavior of known individuals identified through surface and underwater photography. *Rep. Int. whaling commission spec. issue* no. 12, 161-169
Abstract: In the present study, we again found a significant decrease in the numbers and percentage of mother-calf sightings in nearshore waters following the 1977-79 period. In 1980, only 28.3% of mother-calf sets were observed within 0.4km of shore. However, in 1981, the percentage of sightings of mothers and claves in nearshore waters remained low and it has continued to decrease each year thereafter. By 1988, only 1.5% of mothers and claves were observed in waters within 0.4km of shore. Our 1977-88 distribution data demonstrated a decline in the numbers of mothers and claves inhabiting nearshore waters off the west coast of Maui. Increase in human activities in nearshore waters may be adversely affecting the distribution and behavior of mothers and calves, which could possibly result in a decrease in the survival rate of calves and the rate of recruitment to the mature population.

Goodwin L. & Cotton P.A. (2004) Effects of boat traffic on the behaviour of bottlenose dolphins (*Tursiops truncatus*). *Aquatic Mammals* 30, 279-283
Keywords: BOTTLENOSE DOLPHIN/TURSIOPS TRUNCATUS/BEHAVIOR/VESSEL TRAFFIC/CONSERVATION/BEHAVIOR/DISTURBANCE
Abstract: The presence of dolphins in the study area was unrelated to the number of boats present. When boats were stationary, the behavior of dolphins did not differ significantly between boat classes; however, there was a highly significant difference in the response of dolphins to different classes of boats in motion. Speedboats and jet skis were associated with aversive behaviors, even when boats were not directly approaching the dolphins. Dolphins frequently showed negative behaviors (move away, change direction, dive greater than 5 min) in the presence of moving planing-hulled boats. Our study demonstrated that the level of boat traffic might be a poor measure of disturbance. The total number and category of boats did not affect the presence/absence of dolphins or the amount of time they spent in the bay**.** A greater number of negative reactions were recorded in the presence of moving planning-hulled boats compared with moving displacement-hulled and non-motor boats.

Gordon J. & Moscrop A. (1996) Underwater noise pollution and its significance for whales and dolphins. In: (eds. Simmonds M.P. & Hutchinson J.D.), pp. 281-319. John Wiley & Sons, New York.
Keywords: CETACEANS/DOLPHINS/NOISE/NOISE EFFECTS/UNDERWATER NOISE/WHALES
Abstract: It is possible that increased levels of underwater noise could be affecting cetaceans in a number of ways such as interfering with their ability to detect biologically important sounds, disturbing their behavior and impairing their hearing sensitivity. Sounds of the same power have an SPL (sound pressure level) 35.5 dB higher in water than air. The rate at which sound is absorbed by water is inversely related to frequency. Thus lower frequencies, which have very low absorption coefficients, have a greater potential for long-range propagation. In shallow coastal waters, lower-frequency sounds will therefore not propagate well and only the higher frequencies of a broadband sound may be detectable beyond several kilometers. The ability to detect a variety of faint sounds is likely to be of considerable importance to the survival and wellbeing of individual cetaceans, and loss of this sensitivity, even if only temporary could be of substantial survival significance. Elevated stress levels may result from fear, reduced ability to communicate, harassment and displacement. It is technologically possible to reduce most sources of man-made noise in the ocean. Ships could be made much quieter if engines were better engineered and maintained, and mounted on vibration-absorbing blocks. Propellers can be designed to be more efficient and quieter.

Hall J.D. (1982) Prince William Sound, Alaska- humpback whale population and vessel traffic study. Seattle, NMFS.
Abstract: Generally, the animals appeared to be preoccupied with feeding; and it was only when following individual whales at less than 100 yards that any reaction to the boat was apparent. That reaction was often to dive and then either double back or swim at right angles to the direction headed during the preceding series of blows. The whales would thus surface behind or well to the side of the survey vessel at distances of 100 to 600 yards. The presence of the survey vessel appeared not to interfere with feeding activity or disturb social behavior such as pairing, as these activities continued regardless of the presence of the vessel. An exception to the general lack of reaction of the whales to the vessel was with cows with calves. Two mother/calf pairs were sighted and both mother and calf were very wary and avoided the vessel.

Harwood J. (2002) Mitigating the effects of acoustic disturbance in the oceans. *Aquatic Conservation: Marine and freshwater Ecosystems* 12, 485-488
Abstract: What this research and earlier studies, has shown is that a wide range of whale species modify their behavior when exposed to intense sound sources. The critical question is: are behavioral responses a mere inconvenience to the affected animals or might they have a significant effect on their survival or reproduction? We cannot answer this question for any marine mammal species. Changes in behavior in response to disturbance can have profound effects on survival or reproduction that are not immediately obvious from direct observation. These effects can be particularly severe for migratory species that depend on the availability of prey in certain habitats to build up fat reserves in a short period. The US ESA requires federal agencies to ensure that any action they authorize, fund, or carry out does not adversely modify critical habitat for listed species. Disturbance that displaces animals from their critical habitat could legitimately be considered as adversely modifying that habitat.

Hastie G.D., Wilson B., Tufft L.H. & Thompson P.M. (2003) Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science* 19, 74-84
Keywords: Synchrony/Tursiops Truncatus/Bottlenose Dolphin/Scotland/Sac/Conservation/Disturbance/Surfacing Pattern/Calves/Behavior/Nosed Dolphins/Tursiops-Truncatus/Behavior/Whales/Patterns/Vessel/Bay
Abstract: There was a significantly higher probability of synchrony when boat traffic was present in the study area. It is possible that dolphins in this study area consider boats as a threat and synchrony may form part of an anti-predatory type of response in dolphins when in the presence of boats. However, there is an intrinsic link between the spacing of individuals at the surface and breathing synchrony; as synchrony increases, the interindividual distance will decrease. It is possible; therefore, that the observed decreases in spacing observed in these studies are in fact due to increases in breathing synchrony in response to boats. Synchrony may play a role in the social cohesion of the school during periods when it is less efficient to communicate or forage acoustically. The authors conclude that consistent short-term behavioral responses by dolphins could accumulate to produce longer-term consequences for the animals, if they are frequently surfacing to breathe at an energetically inefficient rate, or are consistently precluded from important behaviors such as foraging.

Heckel G., Reilly S.B., Sumich J.L. & Espejel I. (2001) The influence of whalewatching on the behavior of migrating gray whales (*Eschrictius robustus*) in Todos Santos Bay and surrounding waters, Baja California, Mexico. *J. Cetacean Res. Manag.* 3, 227-237
Abstract: The study compared the swimming direction and velocity of whales in the presence and absence of whalewatching vessels, and when other boats were fishing, cruising or drifting. During the southbound migration, whale swimming direction was not different in the presence or absence of whalewatching vessels and other boats. This was, however, statistically different

during the northbound migration both with whale watching vessels and with other boats. Whale swimming velocity showed significant differences without boats and with whale watching boats during both migrations. Analysis of velocity in the absence and presence of other boats did not yield significant differences for either of the migrations. The estimated mean swimming velocity in this study did not increase significantly in the presence of whale watching boats. Velocity variance, however, was significantly different in the presence of whalewatching boats compared to without boats, both during southbound and northbound migrations.

Henry E. & Hammill M.O. (2001) Impact of small boats on the haulout activity of harbour seals (*Phoca vitulina*) in Métis Bay, Saint Lawrence Estuary, Quebec, Canada. *Aquatic Mammals* 27, 140-148
Keywords: BEHAVIOR/DISTURBANCE/ECOTOURISM/HARBOR SEAL/HAUL-OUTS/ ST. LAWRENCE ESTUARY/VESSEL TRAFFIC
Abstract: Disturbances most often were caused by kayaks and canoes (33.3%), motor boats (27.8%), and sailboats (18%). Numbers of seals hauled-out decreased after a disturbance, except during the molting period when seals seemed more reluctant to enter the water. The most severe reaction was seen with the approach of kayak-canoe with a flushing response of 86% compared to 74% by motorboats and 0% by sailboats. Increases in alert behavior by seals occurred during a disturbance but changes were quite subtle. The distance at which at 50% of seals first detected boats (alert distance) occurred when they were up to 800 m away from the animals However, on average seals became more alert when vessels approached to = 300m. No differences in alert distance were observed between seasons or between motor boats and kayaks-canoes. Seals were observed to enter the water (flushing distance) when boats were at distances of > 200 m. The type of boat did not affect the flushing distance.

Hewitt R.P. (1985) Reaction of dolphins to survey vessel: effects on census data. *Fishery Bulletin* 83, 187-193
Abstract: In this study 38% of the schools tracked by helicopter and detected by shipboard observers appeared to react to the ship. Five of 13 schools detected by shipboard observers reacted to the approach of the ship by altering the direction and/or the speed of their movement. One school reacted to the ship prior to shipboard detection.

Hill D., Hockin D., Price D., Tucker G., Morris R. & Treweek J. (1997) Bird disturbance: improving the quality and utility of disturbance research. *Journal of applied ecology* 34, 275-288
Abstract: In estimating the severity and likely impact of disturbance to birds, the following factors should be taken into account: intensity of disturbance; duration and frequency (continuous, infrequent, regular, variable); proximity of source; seasonal variation in sensitivity of affected species; presence of people associated with source; whether birds move away, but return after disturbance ceases; whether regional numbers are affected; whether there are alternative habitats available nearby; whether rare, scarce or especially shy species are affected. So little is known about the roles of density dependence that impacts at the metapopulation level are difficult to predict. Displacement must lead to one or more of: (i) higher densities on sites which are currently used, (ii) a greater proportion of birds being forced to use suboptimal feeding habitat, or (iii) direct mortality if no alternative areas can be found. Most studies report effects based on counts of individuals; with very few investigated disturbance effects on bioenergetics, on population dynamics beyond the focal site, or any impacts on survival probability. These factors are all important in understanding the overall impacts of disturbance rather than simply the effects. The crucial question is whether disturbance reduces the effective carrying capacity of a site through regular activities. Before and after experiments should be conducted at a range of

sites. Activity patterns and temporal and spatial variation in distributions should be recorded systematically.

Janik V.M. & Thompson P.M. (1996) Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science* 12, 597-602
Abstract: In 24 of the 34 observed boat-dolphin encounters we counted fewer surfacings after a boat approached a dolphin than in the minute before. In 8 cases there were more surfacings after a boat arrived, and in 2 cases there was no change. The decrease in surfacings after a boat arrived was highly significant. In 17 of the 22 observed cases involving the dolphin-watching boat we counted fewer surfacings after the boat arrived, in 4 cases there were more surfacings after the boat arrived, and in one case there was no change. Our results showed that the decrease in surfacings after a boat arrived was only significant in cases which involved the dolphin watching boat. The decrease in the number of animals surfacing showed that at least some dolphins either dived for longer periods and/or moved away after the boat approached them. Our results showed that an approaching boat can alter the behavior of dolphins that have been exposed to boats for a long time.

Jansen J.K., Bengtson J.L., Boveng P.L. & Dahle S.P. (2003) *Investigation of the potential disturbance of harbor seals by cruise ships in Disenchantment Bay, Alaska, May to August 2002. Draft report no. 1: field activities and preliminary results*. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA Fisheries, Seattle, WA.
Keywords: HARBOR SEAL/DISTURBANCE/HUMAN INTERACTIONS/CRUISE SHIPS/ALASKA/DISENCHANTMENT BAY/SOUTHEAST ALASKA/YAKUTAT BAY
Abstract: The present analyses indicate that the likelihood of harbor seals vacating ice floes rose steeply when ships approached to less than 500 m; seals approached by a ship at 100 m were 25 times more likely to enter the water than seals approached at 500m. Seals were also four times more prone to enter the water when ships approached them directly, rather than passing abeam. The proportion of seals that entered the water when ships passed within 200 m was nearly 75% compared to less than 10% entering the water at distances (i.e. 600 m) where seals showed no apparent overt response to vessels. Mothers and pups showed no differences in the distance or bearing to vessels at which they were disturbed compared to other seals.

Jensen A.S. & Silber G.K. Large whale ship strike database. (2003). U.S. Department of Commerce.
Abstract: Likely, many ship strikes go undetected or unreported as they may occur in remote areas or struck whales may drift out to sea. Thus, the actual number of strikes is undoubtedly much greater than reported here. Direct reports from ships, crew and captains are the most reliable source of information on an actual ship strike incident. It is often possible to obtain information on ship speed, damage to a ship, and relative degree of severity of the strike to the animal. Ship strike information can also be determined from stranded or floating dead whales. However, these data are not always definitive as to whether the strike occurred pre- or post-mortem. In 42 of the known or probable cases of ship strike in our database, evidence of a collision was only noticed when a whale was brought into harbor on the bow of a large vessel. Most often this occurs with large container, tanker and cruise ships. Given that crew of large vessels often do not detect the impact of striking a whale, animals may be hit and passed over without observation. Likewise, operators may be aware of a strike but choose not to report it. Finback whales are the most often reported species hit (75 records of strike), followed by humpback (44 records). When all 58 reports are grouped by speed, most vessels were traveling in the range of 13-15 knots, followed by speed ranges of 16-18 knots and 22-24 knots. All vessel classes are represented in our database, but it appears generally that relatively large and relatively fast moving vessels are most often involved.

Johnson D. (2002) Environmentally sustainable cruise tourism: a reality check. *Marine Policy* 26, 261-270
Abstract: A fundamental difficulty with sustainability assessments is that of quantifying and costing environmental impacts in the same way that economic benefits can be presented. Furthermore, with marine activities it is particularly difficult to allocate impacts to specific sources. For example, air pollution from seagoing shipping in general, not just cruise ships, is thought to be responsible for a large percentage of the sulfur found in the atmosphere above the oceans. It could be argued that environmentally sound cruises, perhaps, for which tourists also pay some form of _'green levy', should be encouraged to cater for increasing numbers as a more sustainable option than despoiling fragile terrestrial destinations. The impact of non-biodegradable anti-foulings, endocrine disrupting chemicals, which adversely effect the hormonal functioning of marine wildlife, is a specific problem for the shipping industry generally. Gas turbines create less noise and can reduce exhaust emissions by up to 90%. Other examples of technology investment include exhaust gas cleaning devices; a new generation of oil water separators; and homogenizers to reduce nitrogen oxides (No_x) emissions.

Johnson M.P. & Tyack P.L. (2003) A digital acoustic recording tag for measuring the response of wild marine mammals to sound. *IEEE Journal of Oceanic Engineering.* 28, 3-12
Abstract: By comparing the timing of any change in behavior to the sound as heard by the animal, causality can be established in controlled experimental exposures of sound. The extent of the response can then be gauged against received sound level, the first step toward determining suitable exposure limits for a given sound. The playback tanker speed was about 5 knots, and the source level was 170 dB re 1 µPa at 1m, and the range to the tagged whale was 600m. No response was found in the data to this playback. The second playback comprised a recording from a group of right whales socializing in the area. Immediately after the start of the playback, the whale turned toward the playback vessel and resumed its pre-playback course after about a minute. This study demonstrates the ability of the tag to capture subtle, short-term subsurface responses. It may be possible to use tag data to estimate the energetic cost of such responses. This information is sorely needed in setting suitable exposure levels for sound from commercial, defense and research activities and in establishing effective mitigation protocols.

Johnston M.E. (1998) Evaluating the effectiveness of visitor-regulation strategies for polar tourism. *Polar Rec.* 34, 25-30
Keywords: ECOTOURISM/REGULATION/TOURISM GUIDELINES
Abstract: Assessing the effectiveness of a measure through certain steps: 1. determining the specific objectives of the measure; 2. translating the objectives into measurable indicators of achievement; 3. collecting data on the indicators (using a controlled experiment, monitoring, or after-the-fact analysis; and 4. comparing the results with the objectives. At the level of conceptual evaluation, it is necessary to determine the criteria for an effective strategy and to then assess how closely the existing strategy meets those criteria.

Jurasz, C. & Palmer V. (1981a) Distribution and characteristic responses of humpback whales (*Megaptera novaengliae*) in Glacier Bay National Monument, Alaska, 1973-1979.
Abstract: The authors listed behavioral responses in a behavioral hierarchy based on visibility, i.e., least to most, as the concept of an energy expenditure model was first delineated. Listing by visibility also ordered them by energy or mass-motion expenditure. 1.resting/sleeping, 2. traveling, 3. browsing, 4. feeding, 5. vocalization, 6. bubbling-straight line (non feeding), 7. finning, 8. tail lobbing, 9. raking, 10., breaching, 11. avoidance. Numbers 1-4 are considered non-stressed and 5-11 as stressed. The number of behavior changes per hour has steadily increased since 1976. The authors used a model to calculate mean, median, and calculated mode distance in miles between a stimulus and a responding humpback whale. It indicates that

humpbacks may respond to cruise ships at 5.8 miles and killer whales at 5.49 miles. For all other stimuli (fishing-crabbing, charter-pleasure, stern drive, sail with auxiliary, utility craft, kayak-canoe, research vessel), the mode falls to less than a mile from the responding humpback whale (except for another humpback which has a mode of 1.36).

Jurasz C.M. & Palmer V.P. (1981b) Humpback whale (*Megaptera novaeangliae*) and vessel interactions in Glacier Bay National Monument, Alaska: 1976-1979.
Abstract: It was found that when no other vessels were present, 96.2% of the downtimes were less than three minutes. When a vessel was present, the percentage decreased to 85.8% downtimes. When no vessels were present, downtimes greater than five minutes in length occurred 0.4% of the time, but when vessels were present, the percentage of downtimes greater than 5 minutes increased to 6.6%. Data suggests that the 1979 regulations may have been effective in reducing downtime for humpbacks. Whale/vessel interaction responses are predictably higher earlier in the feeding season. The largest number of humpback whales to prematurely depart Glacier Bay did so coincident with the highest rate of whale/vessel interactions. In an examination of cases within the year and over the entire study period the data suggests some form of acclimatizing or habituation occurs. The percentages of encroachment response held well over time while the other, or non-encroachment responses such as feeding, rest/sleeping, and traveling, increased in the presence of the research vessel. If habituation were occurring this trend would be expected.

Kastak D., Schusterman R.J., Southall B.L. & Reichmuth C.J. (1999) Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *J. Acoust. Soc. Am.* 106, 1142-1148
Abstract: These results indicate that noise of moderate intensity and duration is sufficient to induce TTS under water in three pinniped species (1 harbor seal, 2 California sea lions and one northern elephant seal). The disruptions in pinniped behavior were reflected in hauling out, aggression directed at the apparatus and at the trainer and refusal to station at the apparatus during noise exposure. If marine mammals in the wild avoid breeding grounds or feeding locations following exposure to loud sounds regardless of whether a temporary loss of hearing has occurred, there can be dramatic fitness effects, especially if the animals become sensitized to the noxious stimuli. Regardless of the cause, criterion shifts could have dramatic consequences for free-ranging animals, in the form of responding inappropriately to conspecific signals, acoustic cues from potential predators and prey, or irrelevant, nonbiological sound. From these results we conclude that octave band noise levels below about 60 dB SL (sensation level at center frequency) are unlikely to result in a measurable TTS, while moderate exposures of 65-75 dB SL reliably produce small amounts of TTS in three of the four experimental subjects (one young California sea lion showed marginal threshold shift that was statistically unreliable).

King J.M. & Heinen J.T. (2004) An assessment of the behaviors of overwintering manatees as influenced by interactions with tourists at two sites in central Florida. *Biological Conservation* 117, 227-234.
Abstract: The use of protected (no-entry) sanctuaries by manatees was significantly greater when both the numbers of swimmers and boats increased, and when water temperatures were lower in surrounding areas. The time manatees spent bottom-resting and nursing decreased while the time spent milling and swimming increased when swimmers were present compared with when they were absent. The data presented here show that both human swimmers and boats influence manatee behavior in ways that may negatively affect fitness in the winter season. The scan samples showed that manatee use of sanctuaries off-limits to boats and swimmers increased with the numbers of swimmers and boats in the vicinity.

Kipple B. & Gabriele C. (2003b) Glacier Bay underwater noise - August 2000 through August 2002. Naval Surface Warfare Center -- Carderock Division.
Abstract: Medium sized vessels were the most prevalent vessel type at all times of year. At most, large ships were observed in 4 samples per day. The average large vessel noise level was 2 dB higher than the average small vessel level and 7 dB higher than the average medium craft level. Vessel noise is typically due to engine, propulsion system, and propeller related noise. These mechanical systems produce narrowband and broadband noise that is characteristic of vessel and engine type. Small craft with high speed engines and propellers generally produce higher frequency noise while large vessels can generate substantial low frequency noise because of their size and their large, slow speed engines and propellers. All vessels have the ability to produce propeller cavitation noise, which occurs at higher frequencies and is broadband in nature. The sole source of identifiable manmade noise in this study was related to operation of motorized marine vessels. Overall the average vessel noise level was 94 dB, 10 dB greater than the average wind noise. No vessel noise levels exceeded 130 dB at the hydrophone and less than 1% of the samples containing vessel noise had levels above 120 dB. Recommendations include performing an assessment to establish typical noise durations for vessels transiting the length of lower Glacier Bay. This information will be useful to determine the duration of vessel noise influences in the lower bay.

Kipple B. & Gabriele C. (2004) Glacier Bay Watercraft Noise- noise characterization for tour, charter, private, and government vessels. Glacier Bay National Park and Preserve.
Abstract: On the average, overall sound levels were higher for the larger vessel categories. Increased vessel speeds also resulted in higher sound levels. Mechanical systems produce narrowband and broadband noise that is characteristic of vessel and engine type. Small craft with high-speed engines and propellers generally produce higher frequency noise while large vessels can generate substantial low frequency noise because of their size and large, slow speed engines and propellers. All vessels equipped with propellers have the ability to produce propeller cavitation noise, which occurs at higher frequencies and is broadband in nature. Sound levels ranged from a low of 153 dB to a high of 180 dB.

Kipple B.M. (2002b) Glacier Bay underwater noise- interim report. Glacier Bay National Park and Preserve.
Abstract: Marine vessel noise was the only identifiable source of manmade noise that was observed. The highest vessel level recorded was 130 dB, but only about 1% of the peak vessel noise levels exceeded 120 dB at the hydrophone. Medium sized vessels were most prevalent at all times of year. They constituted 62% of all vessel types observed. At most, large ships were observed in 4 samples per day. Average large vessel noise levels were 2 to 5 dB higher than average small and medium craft levels. Vessel noise is typically due to engine, propulsion system, and propeller related noise. These mechanical systems produce narrowband and broadband noise that is characteristic of vessel and engine type. Small craft with high-speed engines and propellers generally produce higher frequency noise while large vessels can generate substantial low frequency noise because of their size and large, slow speed engines and propellers. Months from October through April were roughly 90% free of manmade noise sources.

Kipple B.M. (2002a) Southeast Alaska cruise ship underwater acoustic noise. Report to the GBNP by the Naval Surface Warfare Center - Detachment Bremerton.
Abstract: Cruise ship noise character was typically governed by propulsion system type. This investigation indicates that a 10-knot ship speed limit in Glacier Bay (versus 20 knots) would, in general, result in reduced underwater noise levels, although there could be exceptions. No propulsion system type was clearly quieter than the others were. As ship speed increased,

cavitation noise increased both in level and in the breadth of the range of frequencies over which it occurred. At each range, maximum levels show an acoustic benefit in running at 10 knots versus the higher speed. In general, anytime the horsepower generated by a ship increases, ship noise levels are expected to increase. Based on the knowledge of cruise ship noise gained through this series of measurements, attempts to reduce cruise ship underwater noise levels should focus on propulsion plant related noise and cavitation noise. Recommendations include: establishing the frequency ranges of greatest concern with regard to impact on marine environments; developing underwater noise exposure goals or noise limits so that ship noise levels can begin to be assessed; identify important marine areas where ship noise impacts are of concern; conduct noise measurements on new cruise ship types as they emerge; measure noise from thrusters or other systems that ships might commonly operate.

Kipple B.M. & Gabriele C.M. Glacier Bay Watercraft Noise. (2003a) Detachment Bremerton, Report to GBNP by the Naval Surface Warfare Center.
Abstract: As a group, skiffs under 20 feet in length and 100 horsepower produced the lowest sound levels, followed closely by the jet powered craft, which were the largest and highest powered small craft that were evaluated. The distinct difference between the high-horsepower propeller equipped vessels and the jet-propelled craft indicates that the high-speed propellers are probably an important source of underwater noise. Using one-third octave noise envelopes, noise from the 14 Glacier Bay vessels was compared to the noise from large cruise ships. In these comparisons, cruise ship noise levels were typically higher overall, and at lower frequencies. At frequencies above1 kHz, small craft noise was comparable to, or in some cases greater than, cruise ship levels. In some bands above 1 kHz, the highest noise levels from the higher powered (greater than 100 H.P.), propeller driven craft exceeded the maximum cruise ship levels by up to 13 dB. This result is not surprising given that noise from large, low RPM vessels usually peaks at lower frequencies while noise from small, high RPM craft is typically highest at frequencies above 1 kHz. Sound levels ranged from a low of 157 dB to a high of 181 dB. In terms of overall sound level, cruise ships typically generated more acoustic energy than the most of the small craft discussed in this report.

Koehler N.M. (2001) A Preliminary comparison of Point Adolphus humpback whale scan samples 1999 and 2000. Gustavus, AK, GBNP.
Abstract: In both years whale sightings did not remain constant throughout the day. In 1999, the mean number of whales sighted during the mid-day and evening scans was higher than the mean number of whales sighted during morning scans. In 1999, mean number of vessel sightings was highest at mid-day. In 2000, mean number of vessel sightings was higher in the morning and mid-day than the evening. In 1999, the majority of vessels was sighted at mid-day were personal motorized vessels and charters. The majority of vessels sighted in the morning were commercial fishing vessels. As in 2000, private vessels comprised nearly one-half of all vessels sighted in 1999.

Kovacs A. & Innes S. (1990) The impact of tourism on harp seals (*Phoca groenlandica*) in the Gulf of St. Lawrence, Canada. *Appl. Animal Behavior* 26, 15-26
Abstract: Virtually all aspects of the behavior of mothers and pups were significantly affected by the presence of tourists. Female attendance was significantly reduced and those females that remained with their pups when tourists were present spent significantly more time alert and less time nursing their pups. Pups were more active with tourists present, resting less and changing location more frequently. Pups also spent significantly more time alert and engaged in agonistic behavior. Pup age and tourist behavior affected the degree of disturbance. After the tourists departed, most females returned to their pups promptly and behavior characteristic of undisturbed situations usually resumed within 1 hour. Weaned pups were affected by the presence of tourists

in a manner similar to dependent pups, but somewhat more dramatically. Unlike nursing pups, weaners did not return to undisturbed behavior patterns rapidly. They remained significantly more active, exhibiting behavior patterns intermediate between tourist and undisturbed treatments, statistically most closely resembling the disturbed condition. Groups of people that made modest attempts to minimize disturbance, such as walking calmly and slowly into areas with seals, had discernibly less impact.

Kruse S. (1991) The interactions between killer whales and boats in Johnstone Strait, B.C. In: (eds. Pryor K. & Norris K.S.), pp. p.149; 397-p.159. University of California Press, Berkeley, Ca.
Keywords: BOATS/KILLER WHALE
Abstract: Measures used in this study were: cumulative speed, milling index and course bearing. When boats did not come within 400m of the whales, the author classified observations as presumable undisturbed, control conditions. Killer whales showed a clear response to the presence of boats by swimming, on average, 1.4 times as fast as whales in the undisturbed category. This reaction did not diminish over the course of the summer, indicating that the killer whales did not habituate to the presence of boats. Once in the study area, undisturbed whales did not appear to have preferred swimming directions. Disturbed whales, however, favored a westerly course when moving within the study area. Westward movement may lead the whales out of Johnstone Strait into the open waters of Queen Charlotte Strait (may be escape response). Killer whales did not respond differently to varied boat sizes. Nor did the whales respond differently to outboard motors and inboard engines. Killer whales commonly responded to boats by increasing swim speed but not by changing their course.

Laist L.W., Knowlton A.R., Mead J.G., Collet A.S. & Podesta M. (2001) Collisions between ships and whales. *Marine Mammal Science* 17, 35-75
Abstract: In most cases, whales struck by vessels either were not seen or were seen too late to be avoided. Among collisions causing lethal or sever injuries, 89% involved vessels moving at 14 knots or faster and the remaining 11% involved vessels moving at 10-14 knots; none occurred at speeds below 10 knots. The high proportion of calves and juveniles among stranded ship-struck right whales and humpback whales indicates that young animals may be more vulnerable to being hit by ships.

Leatherwood S.L., Awbrey F.T. & Thomas J.A. (1982) Minke whale response to a transiting survey vessel. *Rep. Int. Whal. Comm.* 32, 795-802
Abstract: Ross Sea minke whales were observed from a helicopter within a 5.5 nm radius of an icebreaker transiting at 12 knots. The whales' swimming directions were uniform at all relative bearings from the ship and all distances tested, suggesting that they were not responding to the vessel's presence. However, a significant proportion of whales observed did approach the icebreaker when it was _'laying to' or making headway at less than about 1 knot. Most whale responses to the aircraft were subtle a change in course, rolling onto the side, or slowly sounding. However, four instances regarded as fright reactions were observed.

Lesage V., Barrette C., Kingsley M.C.S. & Sjare B. (1999) The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River estuary, Canada. *Marine Mammal Science* 15, 65-84
Keywords: Delphinapterus Leucas/Beluga/Odontocete/Whale/Noise /Disturbance/Vocalization/Behavior/St. Lawrence River/Delphinapterus-Leucas/Communication/Whale/Vocalizations/Underwater
Abstract: Vocal responses were observed in all trials and were more persistent when whales were exposed to the ferry than to the small boat. Modifications in the whales "at surface" behavior varied between trials from slightly longer dives or release of bubbles to directional swimming and

departure from the study area. Both vessels induced changes in calling rates, a tendency to emit calls repetitively, an increase in call duration, and an upward shift in the frequency range used to vocalize. However, the effects seemed to be longer lasting when the whales were exposed to the slow moving ferry (as opposed to small, fast motorboat). Our results suggest that these calls do not function solely as alarm calls. In addition to being emitted at a higher rate during boat exposures, falling tonal calls and squawk-type pulsed tones were emitted repetitively and formed series, i.e., were redundant. One reason invoked is that redundancy is a tactic to reduce signal degradation. The shift in frequencies may have been an attempt to increase signal detectability by avoiding frequencies where masking was more severe.

Lewis T.M. & Mathews E.A. (2000) Effects of human visitors on the behavior of harbor seals (*Phoca vitulina richardsi*) at McBride Glacier Fjord, Glacier Bay National Park. Gustavus, AK, GBNP, Resource Management Division.
Abstract: We did not test for statistical differences in these variables, but the data suggests that visitors who remain stationary and quiet are less likely to disturb seals. During pupping, total numbers of seals in the inlet decreased by an average of 42% when a vessel entered the inlet, while seal numbers averaged a 13% increase when no vessels entered the inlet. On average, 7.6 seals were disturbed per encounter and 73% of monitored seals were disturbed. We detected no statistical difference between auxiliary vessels, kayak(s), or pedestrians for either of these variables. The mean number of seals disturbed per hour, however, was highest when pedestrians were involved. Vessels were in the general vicinity of seals for a longer time. Because vessels typically moved throughout the inlet, they had a much greater potential to come into contact with seals than pedestrians did. Vessels also had a larger negative effect on seal numbers counted in the inlet. The majority (59%) of humans entering McBride Fjord either by land or by water did not observe the National Marine Fisheries Service 100 yard minimum approach distance to hauled out seals. The average maximal estimated distance at which disturbance was observed was approximately 190 yards.

Ljungblad D.K., Würsig B., Swartz S.L. & Keene J.M. (1988) Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. *Arctic* 41, 183-194
Keywords: INCOMPLETE/1988
Abstract: All of the surfacing, respiration and dive characteristics showed changes when whales were exposed to seismic sounds at ranges of <10km. Mean blow interval was the only character to increase. The remaining characteristics all decreased significantly when whales were exposed to increasing levels of seismic sounds. The number of blows per surfacing decreased, duration of surfacing, duration of dive and blow rate all decreased. Blow interval increased with exposure to seismic sounds at progressively closer ranges and began to decline once seismic sounds ceased. Values for these behaviors continued to decrease during the first 30-minute post-experiment period and then began to increase toward values equivalent to those before the experiment began. Whales exposed to seismic sounds at close range generally swam fast and only dove for brief times. These data further indicate that the surfacing, respiration and dive characteristics are related, for both physiological and behavioral reasons, and that one variable may be predicted by the changes or pattern of another.

Lusseau D. (2003b) Effects of Tour Boats on the Behavior of Bottlenose Dolphins: Using Markov Chains to Model Anthropogenic Impacts. *Conservation Biology* 17, 1785-1793
Keywords: Tursiops-Truncatus/New-Zealand/Responses/Whale/Bay/Swimmers
Abstract: Socializing and resting behaviors were disrupted by interactions with boats to a level that raises concern. Dolphins were significantly more likely to be traveling after an interaction with a boat. However, the overall behavioral budget of the population was not significantly

affected. The probability of staying in a socializing state and the probability of staying in a resting state were both decreased by interactions with boats. The probability of changing from socializing, milling and resting behavior to traveling behavior was roughly doubled by boat interactions. The behavioral budget of dolphins was different when boat interactions occurred. Overall, dolphins spent more time traveling and diving when boats were present than they did socializing and resting. The decrease in time spent socializing and resting was substantial: socializing bouts were decreased by almost two-thirds and resting bouts by one-third.

Lusseau D. (2004) The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. *Ecology and Society* 9,
Abstract: Boat presence significantly affected behavior transition in the same fashion in both fjords. The probability that a dolphin would start traveling after socializing was affected differently. It increased significantly during boat interactions in Doubtful Sound, whereas it decreased significantly in Milford sound (where boat traffic is five times more dense). The probability of instigating a resting bout from a diving or traveling state was decreased by almost 1.5 times. The probability of staying in a resting state decreased by half, as did the probability of continuing to socialize. Dolphins spent a similar amount of time socializing regardless of boat presence in Milford Sound. In that fjord, only the time spent resting was affected by boat presence (9.1 vs. 2.5%). In Doubtful Sound, all states except milling were significantly affected. The proportion of time spent socializing in Milford Sound was much shorter than in Doubtful Sound. This difference may be related to the high boat traffic in Milford sound. The impact of tourism activities is biologically significant in Milford Sound because tourism forces the population to alter the way in which it uses it home range on a long-term basis.

Lusseau D. & Higham J.E.S. (2004) Managing the impacts of dolphin-based tourism through the definition of critical habitats: the case of bottlenose dolphins (*Tursiops spp*.) in Doubtful Sound, New Zealand. *Tourism Management* 25, 657-667
Abstract: The data provide scientific evidence that determining critical habitat through spatio-ecological analysis is a powerful tool to protect marine mammals in New Zealand, and elsewhere, from biologically significant tourism-induced impacts. A critical region is defined as a location that is predominantly used for socializing or resting. An important region in an area where socializing and resting are often observed. This research clearly demonstrates that the bottlenose dolphins resident in Doubtful Sound do rest and socialize in preferred locations in the fjord and these locations are utilized similarly year-round. Based on this analysis it seems that in the Doubtful Sound context, and possible other contexts too, a multi-level marine mammal sanctuary provides a solution to mitigating the effects of tourism activities on bottlenose dolphins without jeopardizing (and indeed perhaps enhancing) the sustainability of commercial tourism operations.

Lusseau D. (2003a) Male and Female Bottlenose Dolphins Tursiops Spp. Have Different Strategies to Avoid Interactions With Tour Boats in Doubtful Sound, New Zealand. *Marine Ecology-Progress Series* 257, 267-274
Keywords: Bottlenose Dolphin/Tourism/Impact/Avoidance Strategy/Respiration/Truncatus/Responses/Patterns/Whales/Bay
Abstract: I assessed the short-term reactions of bottlenose dolphins Tursiops spp. to interactions with tour boats, and their long-term implications. Vertical avoidance of boats, showed by an increase in time spent underwater, is a typical response in cetaceans, and has been likened to predator avoidance strategies. This study looked at the variation in diving pattern of bottlenose dolphins in Doubtful Sound, New Zealand, in relation to boat interactions. An observing vessel was used to collect the data. A regressive approach showed that this vessel did not have a significant effect on the diving pattern of the dolphins. The analysis would have allowed the detection of a small difference (6.35 s) in dive interval (percentage of variance, PV = 0.05) with

high certainty (power = 0.86). Dolphins avoided tour boats vertically by increasing their mean diving interval. Dolphins started to react before boats were in visual contact. An information theoretic approach indicated that the behaviour of the boat was the predominant factor affecting the diving interval. Males and females responded differently to interactions with boats. Males started to avoid boats as soon as they were present, while females switched to a vertical avoidance strategy only when interactions became intrusive. This difference in avoidance strategy may be related to the different metabolic regime of the sexes. Males would be more likely to meet the cost of vertical avoidance of boats because of their greater energy stores. Females vertically avoid boats, an energetically expensive exercise for them, only when the risk incurred by this interaction is high.

MacArthur R.A., Geist V. & Johnston R.H. (1982) Cardiac and behavioral responses of mountain sheep to human disturbance. *Journal of Wildlife Management.* 46, 351-358
Abstract: In this study 73.9% of all heart rate (HR) responses preceded or occurred in the absence of any motor activity by the sheep. These findings suggest that HR usually recovered to pre-disturbance levels before, or shortly after maintenance activity was resumed. They further imply that so long as the animal is engaged in maintenance behavior, its physiological response to a potential stressor is likely minimal. Deviations from baseline values when standing alert or walking were greater for all trials than deviations recorded during bedding and feeding behavior. Our data also imply greater security (lower HR response to disturbance) with increasing group size. Disturbance to sheep may be minimized by restricting human activities to roads and established trail systems. Note that sheep in this area were already partially habituated to humans.

MacArthur R.A., Johnston R.H. & Geist V. (1979) Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. *Canadian Journal of Zoology* 57, 2010-2021
Abstract: In all ewes HR (heart rate) varied positively with activity level and inversely with distance to a road traversing the study area. Most (78.1%) HR response to disturbing stimuli preceded or occurred in the absence of overt behavioral reactions. The appearance and continued presence (1-10 min) of a human within 50 m of the sheep resulted in a 20% rise in mean HR. Within the sanctuary sheep are frequently exposed to humans and traffic on a graveled access road used heavily for recreation and sheep are habituated to human presence. An increase in HR often preceded or occurred in the absence of any overt locomotor reaction, suggesting preparatory arousal by the animal for possible flight. Though immediate and often dramatic, HR responses to transient stimuli usually terminated rapidly, implying that brief disturbances are not particularly costly in terms of energy expended. Nevertheless, the 20% rise in the mean HR of ewes during continuous exposure to nearby humans indicates that the cumulative effects of these peaks may indeed be energetically significant.

Magalhaes S., Prieto R., Silva M.A., Gonzalves J., Afonso-Dias M. & Santos R.S. (2002) Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. *Aquatic Mammals* 28, 267-274
Keywords: AZORES/DISTURBANCE/HUMAN INTERACTIONS/SPERM WHALE/VESSEL TRAFFIC/WHALE WATCHING
Abstract: Results from land based observations did not indicate changes in the behavior of sperm whales, either due to the presence of boats or when exposed to inappropriate boat maneuvers. From boat-based observations, change in the whale's speed and the presence of aerial displays were significantly more frequent when facing inappropriate boat maneuvers. The presence of swimmers also led to a higher frequency of aerial displays by whales. In the presence of boats, mature females and immature individuals significantly increased their individual mean blow

interval when accompanied by calves. Although some indications of disturbance were detected, we found no clear pattern of short-term reactions of sperm whales to whale watching boats.

Malme C.I. (1987) Behavioral responses of gray whales to industrial noise: feeding observations and predictive modeling. In: (ed Hale D.A.), pp. 97-99. U.S. Department of Commerce, Anchorage, AK.
Keywords: 93OCT/GRAY WHALE/NOISE/ REPRINT FILE
Abstract: Blow rate was found to vary little between control and experimental conditions. Blow interval was found to increase during air gun sound and to decrease during drillship sound; all other behavioral measures (except blow rate) showed the reverse trend. Surface-dive measures for air gun tests did not go back to the pre-exposure values within one hour after the exposure. Drillship values showed the disturbance reaction for up to 30 minutes after the exposure. The disturbance reactions were generally more pronounced for intermediate sound levels than for the higher sound levels. There is some evidence for habituation to a noise stimulus, since continued (and louder) exposures for given whales often produced smaller behavioral changes.

Malme C.I., Miles P.R., Clark C.W., Tyack P. & Bird J.E. (1983) *Investigation of the potential effects of underwater noise from the petroleum industry on the migrating gray whale behavior. Final Report.* Bolt Barenek and Newman, Inc., Cambridge, MA.
Abstract: A measure of hearing sensitivity was obtained, demonstrating that the gray whale can detect the presence of anomalous sounds in the water having a 0 dB signal-to-noise ratio in the 1/3 octave band of maximum signal level (hearing threshold below prevailing ambient noise levels in area). Each playback stimulus caused statistically significant response compared with undisturbed whales, and each stimulus elicited a different pattern of response. The orca playback had the greatest response with whales beyond the 2 km limit of observation moving to avoid the area of sound source. Whales exposed to the drilling platform, helicopter and production platforms also showed avoidance but less pronounced. Aside from deflection from sound source whales also slowed down relative to undisturbed conditions. There were significant differences, independent of range or level of exposure, in milling indices, speed indices, and blow rates for groups prior, during and after exposure.

Malme C.I., Miles P.R., Clark C.W., Tyack P. & Bird J.E. (1984) *Investigation of the potential effects of underwater noise from the petroleum industry on the migrating gray whale behavior. Phase II. January 1984 migration.* Bolt Barenek and Newman, Inc., Cambridge, MA.
Abstract: Migrating whales were found to respond to the presence of a noise source by small course changes at some distance from the source. This “detection” reaction often occurred at ranges where the estimated level of the noise source was equal to the local ambient noise level. In the test area this corresponded to ranges of 2 to 3 km. The result of these small course changes was an increase in the distance between the whales and the source at the closest point of approach. The probability of avoidance analysis procedure showed that avoidance behavior began at sound exposure levels of around 110 dB re 1 ěPa for the playback signals and was greater than 80% for regions with signal levels higher than 130 dB. Levels of 180 dB were observed to produce nearly complete avoidance of the area. The effective range for a 50% probability of avoidance for most of the playback sources was estimated as less than 100m.

Malme C.I., Miles P.R. & McElroy P.T. (1982) The acoustic environment of humpback whales in Glacier Bay and Frederick Sound/Stephens Passage, Alaska.
Abstract: Sound propagation properties of both Frederick Sound and Glacier Bay areas were good with some hard-bottom areas in Glacier Bay providing propagation tending toward cylindrical spreading. Because of low natural ambient noise levels and good transmission properties, the radiated noise from larger ships was a significant contributor to the underwater sound level in

both areas. Vessel and aircraft noise conclusions: radiated noise spectra for those ships that frequent Glacier Bay demonstrate a 20 dB spread in radiated sound energy. Radiated noise of any one particular ship in a reverberant area such as Sitakaday Narrows will be about 10 dB noisier at a given speed than in a non-reverberant area such as mid-channel in the West Arm. Whale vocalization can be louder than average cruise ships and most 10kt small craft in the limited band of 375-415 Hz, when those vessels are 100m away. Some cruise ships will totally mask the whale sounds at this range. Where hard bottoms prevail (such as Sitakaday Narrows, Glacier Bay entrance, east of Willoughby Island, and near the edges of inlets and arms) a maximum speed of 10 knots or less should probably prevail.

Malme C.I., Würsig B., Bird J.E. & Tyack P. (1988) *Observations of feeding gray whale responses to controlled industrial noise exposure*. Jeffries, editors, Port and ocean engineering under Arctic conditions, In: W.M. Sackinger and M.O.
Keywords: INCOMPLETE/1990/GRAY WHALE/NOISE REACTION
Abstract: During drillship playbacks, blow interval decreased and length of surfacing, length of dive and number of blows per surfacing all increased. For air gun sounds, the response was opposite to that of drillship, with blow interval increasing and the other three primary characteristics decreasing. Most of the responses involved either an abrupt change in direction or an increase in speed with apparent movement away from the experimental vessel. For both types of experimental stimuli, subsequent experiments of a day appeared to be affected by the earlier experiments. This took both the form of surfacing-dive data not always going back to a pre-disturbance level after the first experiment of the day, and whales at times reacting less strongly to a subsequent experiment. This is not a firm conclusion, however, because many other factors such as time of day, presence of one or two boats in the area, and general behavior of the whales may have served as confounding factors.

Malme C.I. & Miles P.R. (1990) A method of ranking the disturbance potential of noise sources in the environment of marine mammals in Alaska, In: Alaska OCS Region 3rd Info. Transfer Meet. Conf. Proc., Jan. 30-Feb. 1, Anchorage, p.65-69. OCS Study MMS 90-0041.
Keywords: INCOMPLETE/MARINE MAMMALS (ALASKA)/NOISE
Abstract: The loudest sound sources in the Alaskan marine environment are seismic arrays, icebreakers, large ships, and dredges. Sound levels produced by the smaller vessels used for cargo hauling, fishing, and recreation become significant when several vessels are operating in a relatively small area. Baleen whales are believed to have hearing sensitivity characteristics which include the frequency range of most of the man-made sources described above. As a result, the exposure model showed that the gray, bowhead, fin, and humpback whales which frequent Alaskan waters are species with high probabilities of acoustic interaction with most of the sound sources studied. The model predicted that killer whales, harbor porpoise, Dall's porpoise, harbor seals, and fur seals would be influenced primarily by the loudest sources since their hearing sensitivity does not extend to the low frequency range estimate for baleen whales. The other species studied, including walrus, white whale, and Steller sea lion, were all predicted to have medium to low probability of acoustic influence from the sources considered. This is primarily a result of the fact that their optimal hearing sensitivity is at frequencies above the dominant output frequencies of most man-made sources.

Mathews E.A. (1994) The effects of seismic reflection surveys and vessel traffic on harbor seals in Johns Hopkins Inlet, Glacier Bay National Park: A preliminary assessment. Gustavus, AK, Glacier Bay National Park.
Abstract: The *R/V Alpha Helix,* a 130 foot vessel operated by the National Science Foundation (NSF), was used for the seismic reflection profiling and sediment coring work. Overall, they were in the Inlet approximately 11 hours. The *R.V. Alpha Helix* disturbed 29% of the 436 seals

we observed in or near its path. The two cruise ships disturbed proportionately more seals (86% of 56 seals and 87% of 31 seals) than other vessels. Among the eight vessels we monitored, the seismic survey vessel ranked seventh for this factor, and it was not significantly different from the mean percent of seals disturbed by the other vessels (Mann Whitney-U test).

Mathews E.A. (2000b) Measuring the effects of vessels on harbor seals (*Phoca vitulina richardsi*) at North Marble Island, a terrestrial haulout in Glacier Bay National Park. Gustavus, AK, GBNP.
Abstract: At the beginning of the study we typically observed from 15 to 55 (max) seals on the haulout throughout the day. However, no seals were observed on the haulout during the last 2 days (52 hours) of our observations, following a direct disturbance by a power vessel and use of the haulout by two groups of kayaking campers. In contrast, most seals re-hauled within minutes or a few hours following the 3 earlier disturbances resulting from vessel wakes. Repeated disturbance at seal haulouts could result in reduced survival of pups, disruption of social interactions, increased energy expenditures, protraction of the molt process, increased susceptibility to predation, and/or abandonment of a haulout. In future studies on disturbance and seals, the time between evacuation of a haulout and re-occupation of the haulout should be compared between disturbance events (by categories of vessel type, speed, or distance, and no known disturbance, for example), as the duration for rehauling is an important indicator of the severity of a disturbance.

Mathews E.A. (1997) Preliminary assessment of haulout behavior of harbor seals (*Phoca vitulina*) and sources of disturbance at the Spider Island reefs, Glacier Bay National Park. Gustavus, AK, GBNP.
Abstract: Haulout patterns of harbor during the August molt were markedly different in 1997 compared to previous years. This extreme change in haulout use, coupled with other observations made in 1996 and apparent increases in human activities near the haulouts, suggests that human disturbance may have altered harbor seal behavior in 1997. Peak visitation in Glacier Bay occurs primarily from June through August, exactly the months of sensitive phases in reproduction and molting for harbor seals. The average number of seals during August surveys for 1992-1996 was 1,001 compared to 56 in 1997. Campers were observed at the south tip of Spider Island on the first morning, and on a low island immediately northwest of Spider Island on the second survey day. The lack of seals at the Spider Island reefs during the August 1997 surveys and observations of campers on or near Spider Island on the first two days of these surveys suggest that disturbances by humans may have resulted in at least short term displacement of harbor seals from the main reefs west of Spider Island. However, it is not possible to rule out alternative sources of disturbance, such as predators (killer whales and Steller sea lions) and scavengers (Bald Eagles).

Mathews E.A. (2000a) Reactions of Steller sea lions (*Eumatopias jubatus*) to vessels at a haulout in Glacier Bay. Gustavus, AK, GBNP.
Abstract: Kayakers were significantly more likely to change the behavior of sea lions on the haulout than private operators of power vessels or experienced captains of commercial vessels. Only 1 of 41 tour boats was observed to increase sea lion activity by more than 20% or increase the percentage of sea lions in the water by more than 10%. These observations suggest that vessel noise should be kept low and constant, with engines left on, near haulouts. Factors besides distance influence the potential for disturbance. These factors may include: operator experience, vessel size, changes in noise levels, human activity on deck, initial behavioral state of the animals, wind direction and smell, or the presence of a naturalist familiar with the haulout or sea lion behavior. Habituation to specific vessels could explain some of the reduced reaction to tour boats compared to private and charter vessels, although alternative explanations exist.

Mathews E.A. & Driscoll J. (2001) Disturbance of harbor seals (*Phoca vitulina*) and potential effects on counts from aerial surveys, Glacier Bay National Park, 1991-1999. U. S. National Park Service, GBNPP .
Abstract: Between 1992 and 1999, the number of harbor seals on terrestrial haulouts in Glacier Bay (GB) declined by 50 percent. Twenty of 46 disturbances (43%) were caused by human activities, 10 (22%) by non-human activities, and 16 (35%) by unknown sources. No vessel disturbances occurred when boaters were farther than ¼ nautical mile, and all vessels that approached within 100 yds (n = 7) elicited a disturbance. While disturbance of harbor seals on haulouts may be a factor in the population decline documented in Glacier Bay, it does not appear to be a primary factor. The mean time from a disturbance to full recovery for all cause categories combined was 30 minutes (SD = 36 minutes, n = 19).

Mathews E.A. & Pendleton G.W. (1999) Declining trends in harbor seal (*Phoca vitulina richardsi*) numbers at glacial ice and terrestrial haulouts in Glacier Bay National Park, 1992-1998. Gustavus, AK, GBNP.
Abstract: Numbers of harbor seals on haulouts (resting areas) in Glacier Bay National Park declined by 25-48% between 1992 and 1998. Human disturbance appears to be a partial cause of lower numbers on haulouts, but it only explains a small proportion of the decline at terrestrial sites. Seal numbers at terrestrial haulouts in GB declined by 10.9% per year or -48% from 1992-1998. Local changes in haulout distribution in the Spider Island area accounted for about 6% of the overall decline observed at the terrestrial haulouts. Possible causes of declining numbers of seals on haulouts include increased mortality, reduced birth rates, and/or emigration from GB. Further, increased time in the water, possibly as a result of increased human disturbance or shifts in prey distribution, abundance, or quality, could cause declining trends in seals on terrestrial and glacial ice haulouts in GB. Determining if the observed declines in harbor seals in Glacier Bay National Park are the result of natural fluctuations in the marine environment or due to human activities should be the focus of future research.

Miller G.W., Davis R.A. & Richardson W.J. (1991) *Behavior of bowhead whales of the Davis Strait and Bering/Beaufort stocks vs. regional differences in human activities*. Herndon, VA, U.S. Minerals Management Service.
Abstract: In the thirteen-year period, 1974-1986, various indices of commercial vessel traffic during summer and autumn were 3-5 times higher in the B/B area than in the Davis Strait area. In summary, there are detectable differences in the behavior of the Bering/Beaufort and Davis Strait stocks but only the differences during fall migration seem likely to be related to human activity. The reasons for the regional differences during autumn are uncertain, but the most likely explanation is the ongoing exposure of Bering/Beaufort bowheads to subsistence[3] whaling. There is no evidence that the B/B stock has habituated to the existing levels of human activity.

Mobley J.R. (2005) Assessing responses of humpback whales to North Pacific Acoustic Laboratory (NPAL) transmissions: results of 2001-2003 aerial surveys north of Kauai. *J. Acoust. Soc. Am.* 117, 1666-1673
Abstract: Exposure to the NPAL (formally ATOC) source did not change the numbers of whales

[3] The word "subsistence' as used in the final report refers to the pattern of use of fish, marine invertebrates, wildlife, birds, and plants for sustenance and for social and cultural purposes by the Huna Tlingit. The customary and traditional uses of these species groups is a priority use on Federal lands and waters under the Alaska National Lands Conservation (ANILCA) Title VIII of Act of 1980, *Subsistence Management and Use,* except on any portion of Federal public lands which was permanently closed to such uses on Jan. 1, 1978. Because Glacier Bay National Park lands and waters were permanently closed at that time, subsistence uses do not have a legal or regulatory priority in Glacier Bay National Park lands and waters under ANILCA.

wintering north of Kauai, nor did it produce any discernible distributional changes as measured by the distance from the source and from shore, as well as depths of sighting locations. One of several possible interpretations for this is likely true, either: (a) whales in the study area have habituated to the sound; (b) the current survey design had insufficient statistical power to detect the small levels of distributional change; or (c) distributional changes may have occurred during transmissions, but were not sufficiently long-lasting to be detected.

Mobley J.R., Herman L.M. & Frankel A.S. (1988) Responses of wintering humpback whales (Megaptera novaeangliae) to playback of recordings of winter and summer vocalizations and of synthetic sound. *Behav. Ecol. Sociobiol.* 23, 211-223
Abstract: Three natural sounds and one synthetic sound were played back to humpbacks during their winter residency in Hawaiian waters. The major responses observed during playback was a rapid approach to the playback vessel, characterized in some cases by velocities up to 9 km/h and approaches to within 50 m or less. The approach was selective: 21.6% approached in response to a feeding sound recorded in the summer feeding grounds in Alaska; 8.3% approached in response to social sounds recorded in the Hawaiian winter grounds in the presence of large surface-active pods; 3.4% responded to playback of winter song; and 4.1% responded to playback of synthetic sound. There were no approach responses to the blank tape control.

Moore S.E. & Clark J.T. (2002) Potential impact of offshore industrial activities, vessel traffic and whale-watching on grey whales. *Paper presented to the IWC Scientific Committee*
Abstract: Studies of short-term behavioral responses to underwater noise associated with aircraft, ships and seismic explorations indicate a 0.5 probability that whales will responds to continuous broadband noise when sound levels exceed *ca* 120 dB re: 1 Pa and to intermittent noise when levels exceed *ca* 170 dB, usually by changing their swimming course to avoid the source. Gray whales were _'startled' at the sudden onset of noise during playback studies, but demonstrated flexibility in swimming and calling behavior that may allow them to circumvent increased noise levels. In general, as nose levels increased there was a corresponding increase in calling rates, level of calls received, number of frequency-modulated calls, number of pulses produced per pulsed-call series and call repetition rate. The recovery of the gray whale population in the face of long term exposure to human activity along the North American coast suggest a strong degree of tolerance to such activities. Long-term research should be directed at investigating whether there is a limit to such tolerance by examining changes in relative abundance and migration routes near centers of human activities over a number of years.

National Research Council (2005) *Marine mammal populations and ocean noise: determining when noise causes biologically significant effects*. National Academies Press, Washington, DC.
Keywords: NOISE/MARINE MAMMALS/IMPACT/BIOLOGICALLY SIGNIFICANT EFFECTS
Abstract: Individual based models can be used to provide preliminary understanding and to identify the most crucial gaps in available data. More data on assessments of hearing characteristics such as absolute sensitivity, masking, temporary threshold shifts, and temporal integration, and on the evaluation of behavior during exposure needs to be acquired. Because the extent of the stress response often correlates with the general health of an animal, measuring the response can serve as a general indicator of the current condition of an animal, reflecting its health, its energy allocation, and the effect of human disturbances on it. Although there are many documented, clearly discernable responses of marine mammals to anthropogenic sound, reactions are typically subtle, consisting of shorter surfacings, shorter dives, fewer blows per surfacing, longer intervals between blows, ceasing or increasing vocalizations, shortening or lengthening duration of vocalizations, and changing frequency or intensity of vocalizations. Although some of these changes become statistically significant in given exposures, it remains

unknown when and how these changes translate into biologically significant effects at either the individual or the population level.

Ng S.L. & Leung S. (2003) Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research* 56, 555-567
Abstract: The ANOVA results indicated that the length of dive time was affected by traffic density, vessel association and response type, but not by fairway association. There was a significant inverse relationship between dive duration and degree of vessel association. When dolphins were situated in an area of heavy vessel traffic or there was the presence of an oncoming vessel, they were believed to be in a state of anticipation so that longer duration dives were performed. A high rate of negative and undetermined responses to high-speed vessels indicated that these vessels caused the greatest disturbance to the dolphin community. There are two possible reasons for this: a high-speed vessel being a fast moving object might scare the dolphins, or the second reason is the noise produced.

Nishiwaki M. & Sasao A. (1977) Human activities disturbing natural migration routes of whales. *Sci. Rpt. Whales Res. Inst. Tokyo* 29, 113-120
Abstract: Results show the apparent disturbances by ships and boats to the migration routes of Baird's beaked whales and minke whales. This is based on observation only.

Nowacek S.M., Wells R.S., Owen E.C.G., Speakman T.R., Flamm R.O. & Nowacek D.P. (2004) Florida manatees, *Trichechus manatus latirostris*, respond to approaching vessels. *Biological Conservation* 119, 517-523
Abstract: Manatees in shallow waters and at the edge of the channel responded to approaches by orienting towards the nearest deep water, a boat channel, and increasing their swimming speed. Close boat approaches and shallow water depths exacerbated these responses. Our results indicate that manatees detect and respond to approaching vessels with an apparent flight response, a response that includes movement towards deeper water. No clear patterns were found for the remaining behavioral variables of heading, swimming depth, inter-animal distance, and mobility as indicators of response to boat approaches. Significant changes were detected only during close approaches; no significant changes in swimming speed were seen when the boat passed farther than 25m from the focal animal.

Nowacek S.M., Wells R.S. & Solow A.R. (2001) Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Mar. Mammal Sci.* 17, 673-688
Keywords: BOTTLENOSE DOLPHIN/CONSERVATION/DISTURBANCE/FLORIDA /HUMAN IMPACT/VESSEL TRAFFIC
Abstract: Changes in heading, inter-animal distance and swimming speed were identified from digital video segments. The continuous observations showed that dolphins are making quick, and sometimes subtle, changes in heading, swimming speed, and/or inter-animal distance. These changes occur rapidly and are unlikely to be observed at their actual frequency of occurrence by examining surface behaviors alone. Our findings indicate that duration of exposure alone could be a predictor for impact on dolphin behavior. The second probable cause of disturbance is the rate of change by the source disturbance. Erratic approaches caused far more changes in heading and inter-animal distance than either slow or fast approaches. Water depth appears to be a confounding factor. The resident community of bottlenose dolphins in Sarasota Bay coexists with a high level of boat traffic with an average of six minutes between vessel approaches (within 100m) during daylight hours. Despite dolphins' long-term exposure to boat traffic, short-term behavioral responses were documented.

Orams M.B. (2002) Humpback whales in Tonga: an economic resource for tourism. *Coastal Manage.* 30, 361-380
Keywords: ECONOMIC IMPACT/ECOTOURISM/HUMPBACK WHALE/PACIFIC OCEAN/TONGA/WHALE WATCHING
Abstract: The growth of whale-watching internationally has been spectacular. It now occurs in almost 100 countries and is estimated to be worth in excess of U.S.$1 billion each year in revenue. Thus, whales have become valuable as a resource for tourism. The Vava'u island group in the northern part of the Kingdom of Tonga in the South Pacific is an area with a growing reputation as a whale-watching destination. However, the industry is relatively new there and the impacts of whale-based tourism in these islands is, as yet, unknown. In addition, there has been a recent consideration of a return to hunting whales in Tonga. As a result, concerns regarding the value of these animals for tourism and the potential impact of a return to hunting have arisen. Consequently, a study was designed to provide a preliminary assessment of the economic impacts of these animals for the island community. This study estimates that humpback whales may be worth in excess of U.S.$700,000 annually as a tourism attraction and that there is significant potential for future growth. Furthermore, the study shows that current visitors are opposed to any resumption of whaling practices in the islands and that such a move would likely displace large numbers of tourists from Tonga. Thus, it is concluded that a resumption of whaling in Tonga would likely have a significant opportunity cost in terms of lost tourism revenues.

Orams M.B. (2000) Tourists getting close to whales, is it what whale-watching is all about? *Tourism Management* 21, 561-569
Keywords: ECOTOURISM/MANAGEMENT/NEW ZEALAND/WHALE WATCHING
Abstract: To date research on whale-watching has tended to focus on impacts on the whales. Management approaches often rely on minimum approach distances. An associated assumption is that whale-watchers wish to get close to whales. Studies of motivation for other recreational activities show that humans seldom undertake recreational activities for simplistic reasons. Thus, this study was developed to determine the influences over whale-watchers' enjoyment, more specifically, to assess the importance of the geographical proximity of whales. Twelve whale-watch cruises at Tangalooma, Australia were surveyed and 704 questionnaires analyzed. Results showed the number of whales and their behaviour, numbers of fellow passengers, cruise duration, boat construction and sea-sickness influenced satisfaction. The geographical proximity of the whales was not a major influence. Many whale-watchers (35 per cent) returned satisfied even when no whales were sighted. Whale-watching is not simply about getting close to whales, many other variables are important. A better understanding of the watchers, as well as the whales, will assist in the sustainable management of this growing tourism industry.

Patenaude N.J., Richardson W.J., Smultea M.A., Koski W.R., Miller G.W., Wursig B. & Greene C.R. Jr. (2002) Aircraft Sound and Disturbance to Bowhead and Beluga Whales During Spring Migration in the Alaskan Beaufort Sea. *Marine Mammal Science* 18, 309-335
Keywords: Bowhead Whale/Balaena Mysticetus/Beluga Whale/Delphinapterus Leucas /Beaufort Sea/Alaska/Arctic/Aircraft Disturbance/Aircraft Sound/Underwater Noise/Helicopter/Behavior/Hearing Thresholds/Balaena-Mysticetus/Behavior
Abstract: Mid-frequency sound components, visual cues, or both, are probably important in eliciting beluga reactions to aircraft. Helicopter sounds were generally stronger than fixed-wing aircraft sounds. Proportions of whale groups observed to react tended to be higher for a helicopter than for a fixed-wing aircraft. Reactions were (as expected) most commonly seen when the aircraft altitude was less than 150-180 m and the aircraft flew either directly overhead or within a lateral distance of about 250 m.

Polacheck T. & Thorpe L. (1990) *Report to the International Whaling Commission* 40,
Abstract: Animals were observed to be swimming in directions away from the track line significantly more frequently than towards it, and this behavior was more frequent for animals sighted within 400m of the vessel than for animals seen at greater distances.
Harbor porpoise regularly congregate in the study area and ship traffic in this area (including a regular ferry service) is frequent. Animals might have been expected to have become habituated to vessel noises and movements. These results suggesting avoidance behavior were unexpected. This study and previous studies support the hypothesis that harbor porpoise and minke whales exhibit avoidance reactions to survey vessels.

Rendell L. & Gordon J.C.D. (1999) Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. *Marine Mammal Science* 15, 198-204
Abstract: During this acoustic survey, sonar-type sounds were recorded at 12% of monitoring stations. When different classes of whistle were tested independently, "level", "up-down" and "down-up" whistles all occurred significantly more during and just after sonar output than at other times. The results are strongly indicative of a tendency for pilot whales to respond vocally to military sonar pulses. The effect was being elicited at a considerable range from the source (at no time during the pilot whale encounter was a possible sonar-emitting vessel observed) and that the whales appeared not to have habituated to the signal after several hours of exposure.

Richardson W.I., Fraker M.A., Wursig B. & Wells R.S. (1985) Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: reactions to industrial activities. *Biological Conservation* 32, 195-230
Abstract: When some experiments began, the whales were socializing, playing with a log, or probably feeding; these activities were replaced by rapid and directed swimming. Whales that had originally been closely grouped sometimes were scattered widely after the boat moved away. Sensitivity to boats seemed quite variable. Bowheads often responded at 2-4 km, but others did not begin to move away until the boat was within 0.8-1 km. Our observations from an aircraft show that boat-based observers sometimes do not detect whales that move away from the boat when it is still a few km away. Thus, other species may react more strongly than the literature suggests. General activities in the presence of seismic noise seemed normal- surfacing and diving, feeding, socializing, calling and sometimes traveling. There was sometimes evidence of subtle changes in surfacing, diving and respiration behavior. We cannot be sure that the weak and inconsistent trends were attributable to seismic noise. The results show some tolerance of drillship operations by bowheads, but the playback experiments suggest that avoidance may sometimes occur. Conclusions: stimuli to which there are no detectable short-term reactions might nonetheless produce long-term effects, e.g. through stress or reduced tendency to return to the same area in future years. These results suggest that bowheads tend to react to transient or recently-begun industrial activities, but often tolerate considerable noise from operations that continue with little change for hours or days.

Richardson W.J., Davis R.A., Evans C.R., Ljungblad D.K. & Norton P. (1987) Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-1984. *Arctic* 40, 93-104
Abstract: Our data suggest that seismic exploration has not caused large-scale abandonment of parts of the summer range. However, bowheads were apparently abundant in the central MIA (main industrial area) in 3 of 5 years from 1976 to 1980 but in 0 of 4 subsequent years. The intensity of offshore industrial activities increased gradually from 1976 to 1983-84, and it can be hypothesized that industry began to affect bowhead distribution after 1980. Year to year changes in bowhead abundance occurred outside as well as within the MIA. Industrial activity cannot account for all changes outside the MIA. If distribution outside the MIA varies because of

natural factors, reduced use of the MIA might be the result of similar natural factors. Factors affecting copepods and other zooplankton probably influence bowhead distribution. However, the "food hypothesis" would require that there were year-to-year changes in food availability within the MIA in 1980-84, which has not been demonstrated. There was no evidence that bowheads avoid areas of seismic exploration. However, after 1980 fewer bowheads entered the main area of drilling, dredging and support activities, particularly its central zone. One hypothesis is that cumulative effects of industry have led to avoidance. Another hypothesis is that bowhead distribution varied in response to expected (but unproven) year-to-year changes in food supply. Both factors may be involved.

Richardson W.J., Finley K.J., Miller G.W., Davis R.A. & Koski W.R. (1995) Feeding, social and migration behavior of bowhead whales, *Balaena mysticetus*, in Baffin Bay *vs*. the Beaufort Sea--regions with different amounts of human activity. *Mar. Mammal Sci.* 11, 1-45
Keywords: BAFFIN BAY/BEAUFORT SEA/BEHAVIOR/BOWHEAD WHALE/BOWHEAD WHALE (DAVIS STRAIT/BAFFIN BAY STOCK)/FEEDING/HUMAN IMPACTS/MIGRATION/SOCIAL BEHAVIOR
Abstract: The behavior of East (E) and West (W) Arctic bowheads observed in undisturbed situations during the late summer/early autumn period was similar in many ways. This occurred even though W bowheads had been exposed to more human activities in recent years. However, there were a number of significant E-W differences in behavior. Some of these can be ascribed to E-W differences in environmental condition, age classes of whales, and types of whale activities observed. Other E-W differences in behavior, notably during autumn migration, are not readily attributable to these last factors. Exposure to human activities in the W arctic may have been a factor, but causative links cannot be isolated.

Richardson W.J., Greene C.R., Hanna J.S., Koski W.R., Miller G.W., Patenaude N.J. & Smultea M.A. (1995) *Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska - 1991 and 1994 phases: sound propagation and whale responses to playbacks of icebreaker noise*. U.S. Department of the Interior, Herndon, VA.
Keywords: ACOUSTIC EFFECTS/BELUGA WHALE/BOWHEAD WHALE/OIL AND GAS EXPLORATION IMPACT/OIL EXPLOITATION
Abstract: Migrating bowheads tolerated exposure to high levels of continuous drilling noise if this was necessary to continue their migration. Bowhead migration was not blocked by the sounds and there was no evidence that bowheads avoided the projector by distances exceeding 1 km. Surfacing and respiration behavior, and the occurrence of turns during surfacings, were strongly affected out to 1 km. Turns were unusually frequent out to 2 km, and there was evidence of subtle behavioral effects at distances up to 2-4 km. We concluded the effects were not biologically significant. In general, movements and behavior of migrating bowheads exposed to playbacks of variable icebreaker noise were altered subtly but statistically significantly when S:N exceeded 20 dB, and when RL (received level) of icebreaker sound exceeded 100 dB re 1 μPa. We conclude drilling sounds would have no biologically significant effects of migration routes and spatial distribution of white whales.

Richardson W.J. & Wursig B. (1996) Influences of Man-Made Noise and Other Human Actions on Cetacean Behaviour. *Marine and Freshwater Behaviour and Physiology* 29, 183-209
Keywords: Underwater Noise/Impacts/Disturbance/Masking/Whales/Dolphins/Canadian Beaufort Sea/Whales Balaena-Mysticetus/Bowhead Whales/Hearing Thresholds/Humpback Whales /Beluga Whale/Sperm Whales/Underwater/Responses/Atlantic
Abstract: A circling observation aircraft sometimes causes subtle changes in surfacing and respiration patterns, demonstrable only by statistical analysis, even when there is no sudden dive

or other conspicuous response. Thus, the absence of conspicuous responses to an aircraft (or other human activity) does not prove that the animals are unaffected. Avoidance reactions by cetaceans may occur beyond the visual range of observers on the approaching vessel. Boat-based observers may have a biased perception of reaction distances, seeing only the less-responsive individuals. When exposed to strong seismic pulses (>160 dB), both bowhead and gray whales tend to have unusually short surfacings and dives, and fewer blows per surfacing. This is a common behavioral change in whales disturbed by human activities. Reaction thresholds tend to be low when the sound is novel or its level is increasing. Reaction thresholds tend to be higher for steady sounds, e.g. from stationary industrial activities; and higher still for pulsed sounds, e.g. seismic noise. Reaction thresholds vary widely even for one species and one sound type. Cetaceans are often less responsive when feeding, socializing or mating than when resting. They may be more responsive when movements are restricted by a shoreline, shallow water, or ice. Radii of audibility and responsiveness can be predicted if one knows (or can estimate) the source level of a man-made noise, its propagation loss, ambient noise, hearing thresholds, and behavioral response thresholds. This exercise requires many assumptions but, at the least, is useful in identifying some key data gaps.

Richardson W.J., Wursig B. & Greene C.R. (1990) Reactions of Bowhead Whales, *Balaena mysticetus*, to Drilling and Dredging Noise in the Canadian Beaufort Sea. *Marine Environmental Research* 29, 135-160
Abstract: Most bowhead whales do not react overtly to drillship and dredge sounds unless their levels are 20 or 30 dB above ambient, i.e. 20 or 30 dB above the assumed detection threshold. Since noise levels received from a point source of industrial sounds diminish with increasing distance, the radius of responsiveness of bowheads to industrial sounds is apparently considerably less than the radius of audibility. The playback tests suggest that many bowheads would react at distances of 4-10 km from the drillship or 3-11 km from the dredge. Nonetheless, we saw some bowhead whales as close as 4km from the actual drillship and 0.8 km from the dredge. At least two factors were probably involved: variable responsiveness and habituation. The presence of a few whales close to drillships and dredges does not prove that these industrial activities have no effect on whales at those distances. The bowheads seen close to the actual drillship or dredge may have been among the less sensitive individuals.

Richardson W.J., Wursig B. & Greene C.R. (1986) Reactions of Bowhead Whales, Balaena-Mysticetus, to Seismic Exploration in the Canadian Beaufort Sea. *Journal of the Acoustical Society of America* 79, 1117-1128
Abstract: When matched results from all 5 years were pooled bowheads in the presence of seismic noise tended to have fewer blows per surfacing, marginally shorter surfacings, shorter dives, and longer blow intervals. Estimated speeds were similar with and without seismic noise. Their average calling rates were only slightly less than rates near undisturbed whales. General activities of bowheads were rarely if ever, altered noticeably by noise from seismic vessels 6 km or more away. Bowhead whales reacted to close approach by an operating seismic vessel, but not abruptly. Near-bottom feeding ceased at a range of 3 km. The minimum level of noise impulse necessary to cause physical damage to a bowhead's auditory system is not known, but is probably >160 dB. Bowhead whales react to intense pulses of seismic noise by interrupting their normal activities and moving away. Reactions begin when full-scale seismic vessels approach within about 7.5 km, even though noise pulses are often detectable 25-90 km away. Evidence of subtle behavioral effects >7.5 km away is suggestive but inconclusive. Part of the reaction to a close seismic vessel may be to its continuous engine or machinery noise. However, airgun tests showed that bowheads react to strong seismic pluses per se by moving away. Thus bowheads can localize the direction of arrival of these noise pulses.

Richardson W.J. (1999) *Marine mammals and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998*. LGL Limited Environmental Research Associates and Greeneridge Sciences, Inc., King City, ON ; Santa Barbara, CA.
Keywords: ACOUSTIC EFFECTS/ACOUSTICAL SURVEILLANCE/ALASKA/BEAUFORT SEA/BELUGA WHALE/BIOACOUSTICS/BOWHEAD WHALE/GRAY WHALE/MARINE MAMMALS/NOISE/OIL EXPLORATION/ RINGED SEAL/SEISMIC EXPLORATION IMPACT/SEISMIC SURVEYING
Abstract: The operation of an airgun array had effects on the distribution and (to some limited extent) the behavior of some of the seals within a few hundred meters of the array. Overall, the 1996-98 data show that most bowheads avoided the area within about 20 km of the operating airguns. General activities of bowheads were similar at times that were and were not influenced by seismic. During seismic operations the closest sighting of a gray whale was about 25 km away (as opposed to 10 km during no-seismic periods).

Richardson W.J. (1993) Reactions of migrating bowhead and beluga whales to noise from simulated industrial activities in ice leads during spring. In: (ed Sciences M.A.E.), pp. p. 95-99. U.S. Department of Interior, Anchorage, AK.
Keywords: 93DEC/BELUGA WHALE/BOWHEAD WHALE/NOISE REACTION/REPRINT FILE
Abstract: Belugas showed no obvious reaction to the steady drilling sound until they approached within 200-400 m. Even then the reactions were inconsistent and brief. Playbacks of continuous low-frequency drilling noise did not cause biologically significant alterations in the migration route of bowhead whales visible in open water amidst the pack ice and in parts of the nearshore lead system during spring migration east of Point Barrow. There were, however, small-scale alterations in the courses of some individual whales that come within 1 km. There were also statistically significant changes in many other aspects of the behavior of bowheads approaching within 1km of the projector. A few behavioral variables were apparently affected at distances out to 2-4 km. The biological significance of these changes in bowhead behavior is less obvious; most aspects of behavior that were affected near the noise source were affected for only about .5-1 hour.

Richardson W.J. & Malme C.I. (1993) Man-made noise and behavioral responses. In: (eds. Burns J.J., Montague J.J. & Cowles C.J.), pp. 631-700. The Society for Marine Mammalogy, Lawrence, KS.
Keywords: 93JUN /BOWHEAD WHALE/NOISE AND BEHAVIORAL RESPONSE/REPRINT FILE
Abstract: In general, bowheads react strongly and rather consistently to approaching vessels of a wide variety of types and sizes. Bowheads interrupt their normal behavior and swim rapidly away. Surfacing, respiration, and diving cycles are affected. Vessels moving slowly and in direction not toward the whales usually do not elicit such strong reactions. Physiological reactions such as elevated heart rate or other manifestations of "stress" may occur even if no overt behavioral response is evident. Observational data on surfacing, respiration, and dive variables may be useful indirect indicators of physiological state. The strong flight reactions of bowheads to approaching boats and seismic ships usually cease within 0.5 h after the boat passes, at which time whales can be as much as 5 km from their original locations. The significance of single or repeated displacements of this magnitude is uncertain.

Richter C.F., Lusseau D., Martinez E. & Slooten E. (2000) A review of methodologies employed to assess impacts of boat-based marine mammal-watching activities on cetaceans. *IWC Scientific Committee* SC/52/WW19., 14pp
Abstract: The authors attempt to develop an efficient and standardized methodology to assess

impacts of cetacean-watching activities. They suggest the following guidelines to render studies on various species and under a range of conditions comparable and easy to interpret: (a) establish biologically significant control conditions. (b) choose more than one dependent variable. (c) consider concurrent changes of impact variables and natural conditions. (d) report effect size relative to natural variability of the dependent variable. (e) use land-based observations to obtain control conditions. (f) long-term studies are needed to establish baselines for environmental impact statements.

Salden D.R. (1988) Humpback whale encounter rates offshore of Maui, Hawaii. *Journal of Wildlife Management* 52, 301-304
Keywords: 1988
Abstract: The author believes that like Watkins (1986) findings of humpbacks habituating to boats in Cape Cod Bay, humpbacks in Hawaii have also habituated. Calf encounter rates reflect slight, but not statistically significant, increases so human activities throughout Maui County have not caused a decline of whales or calves. However, the relative frequency of calf encounters in waters adjacent to tourist centers has decreased. At the same time the relative calf encounter rates in waters 3-4 km from shore have increased. Hence, the shift towards less congested waters off Maui by cows and calves is evident and consistent. The whales appear to be moving offshore. The possibility that boating activity in these areas is causing this displacement needs to be investigated. Ultimately, it is possible that human activity within these resting areas could have a negative impact on humpback calving rates, especially if comparable habitats free from human occupation are not available.

Scarpaci C., Bigger S.W., Corkeron P.J. & Nugegoda D. (2000) Bottlenose dolphins (*Tursiops truncatus*) increase whistling in the presence of "swim-with-dolphin" tour operations. Journal of Cetacean Research and Management [J. Cetacean Res. Manag.]. 2[3], 183-186.
Abstract: The impact of cetacean eco-tourism on subject animals is not clearly understood. Studies that monitor this impact have traditionally concentrated on observable surface behaviour despite the fact that sound is the primary communication channel for cetaceans. This study monitored whistle production in free ranging bottlenose dolphins (Tursiops truncatus) to evaluate if dolphins vocalize at different rates in response to commercial dolphin-swim boats. Thirty-two hours of sound were recorded in the austral spring and summer of 1995/96. Results indicate that whistle production is significantly greater in the presence of commercial dolphin swim boats, regardless of dolphins' behavioural state prior to the arrival of the vessels. The increase in whistle production suggests that group cohesion may be affected during approaches made by commercial dolphin swim tour-operators or may serve some other social function. Monitoring vocal behaviour offers another insight into short-term human impacts on cetaceans

Scheidat M., Castro C., Gonzalez J. & Williams R. (2004) Behavioural responses of humpback whales (*Megaptera novaeangliae*) to whalewatching boats near Isla de la Plata, Machalilla National Park, Ecuador. *Journal of Cetacean Research and Management* 6, 63-68
Keywords: HUMPBACK WHALE /WHALE WATCHING/ECOTOURISM/DISTURBANCE/HUMAN INTERACTIONS/BEHAVIOR/ECUADOR/SOUTH AMERICA
Abstract: Whales reacted to the approach of whale watching boats by increasing swim speed significantly, and adopted a much more direct path after boats left. Speed did not decline significantly after the vessel left. Whales' paths, however, became significantly more direct. Weak evidence was found that swim speed decreased in the 20 minutes of observation after boats left. Whilst this is not significant at the p=0.05 level, it is suggestive of the prediction that the effect is short lived. The nature and apparent strength of humpbacks' response to disturbance is striking. It is interesting to note that humpback whales increased speed by over 50% in this

study, and perhaps as much as 300% in Hawaii (Au and Green, 2001), while the mean response of northern resident killer whales was to adopt a path that was 13% less direct (Williams et al. 2002).

Smethurst D. & Nietschmann B. (1999) The Distribution of Manatees (*Trichechus manatus*) in the Coastal Waterways of Tortuguero, Costa Rica. *Biological Conservation* 89, 267-274
Keywords: Costa Rica/Manatees /Hunting/Deforestation/Environmental Degradation/Trichechus Manatus
Abstract: Manatees are concentrated in areas where environmental degradation is least. The place where most sightings were made, is the only waterway that is entirely protected within the park and the only waterway where no deforestation has occurred upriver. Boat traffic appears to play a role in manatee distribution. We conclude that manatees avoid areas where boat traffic is high. There was an inverse correlation between boat traffic and manatee sightings. Our data indicate that there is a strong correlation between manatee sightings and areas that are not degraded nor heavily trafficked by boats.

St. Aubin D.J. & L.A. Dierauf L.A. (2001) Stress and Marine Mammals. In: L.A. Dierauf and F.M.D. Gulland, ed., CRC Handbook of Marine Mammal Medicine, 2nd ed. Boca Raton, FL, CRC Press, 1063 p. .
Abstract: When an individual can predict and control the threatening stressor, a coping mechanism can be established. However, when the responses to stress are uncontrolled, excessive, and prolonged, a state of distress results. Anxiety is often the first outward sign of an animal under stress. Chronic stress may occur if stressors are frequent, intermittent, and/or repetitive. Impaired growth and reproduction, frequent infection, and pathological changes in organs are among the many consequences that can be linked to chronic stress.

Suryan R.M. & Harvey J.T. (1999) Variability in reactions of Pacific harbor seals *Phoca vitulina richardsi*, to disturbance. *Fisheries Bulletin* 97, 332-339.
Abstract: Those seals remaining or returning to shore after harassment were more tolerant of powerboats, allowing significantly closer approaches than those initially harassed. Seals detected (head raised or oriented toward the potential disturbance) a powerboat at a mean distance of 264 m, and harassments occurred when boats approached, on average, to within 144m. The primary cause of disturbance was powerboats, then unknown, and third was bald eagles. Sea kayakers were a greater potential disturbance to seals ashore than operators of powerboats (but were uncommon in the study). Pups did not appear to be affected disproportionately to subadults and adults to disturbance. 25% of harassments occurred when vessels were <100 m from seals, 50% occurred at 100-200 m, and 25% at 200-300 m. Overall, only 39% of all harassments resulted in full recovery, indicating seals often remained in the water or moved to a different site. Results indicated that seals at a pupping location were affected more by disturbance.

Taylor B.L. & Dawson P.K. (1984) Seasonal Changes in Density and Behavior of Harbor Porpoise (*Phocoena phocoena)* Affecting Census Methodology in Glacier Bay National Park, Alaska.
Abstract: A behavior called _'pop-splashing' where the porpoise moved faster than normal and surfaced with a vigorous vertical motion causing a vertical splash was often seen in response to the approach of boats. Typically a porpoise would be seen roll surfacing, would pop-splash as a boat approached, and would return to roll surfacing after the boat passed. Of the 38 porpoises encountered on the Feb. 1980 boat survey, 60% were observed to pop-splash upon approach and return to roll surfacing after the vessel passed.

Thomas J.A., Kastelein R.A. & Awbrey F.T. (1990) Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. *Zoo Biology* 9, 393-402
Abstract: Swim patterns, social groups, and respiration/dive rates were not statistically different before and during playbacks. We assayed levels of blood catecholamines before and after playbacks as a measure of stress. Blood epinephrine and norepinephrine levels measured immediately after playbacks were not elevated. Using the parameters we selected, we could not detect any short-term behavioral or physiological effects of drilling noise playbacks on these captive belugas. There was an initial flight response by some animals when the noise playback started but belugas soon accommodated and showed no change in swim pattern or social groups.

Thompson P.O., Cummings W.C. & Ha S.J. (1986) Sounds, source levels, and associated behavior of humpback whales, Southeast Alaska. *j. acoustic soc. am.* 80, 735-740
Abstract: Humpback whales in southeast Alaskan waters produced five categories of sounds: moans, grunts, pulse trains, blowhole-associated sounds, and surface impacts. Frequencies (Hz) of moans and grunts were 20-1900. Major energy in low-frequency pulse trains was in a band of 25-80 Hz with pulse duration of 300-400ms. Blowhole associated sounds, recorded as transiting whales encountered one another, were of two types: shrieks, 555-2000 Hz, and trumpet like horn blasts with fundamental at 414 Hz (median). Pulses and spread spectrum noise were associated with gas bubble formation and explosive bursts, respectively, in connection with spiral feeding maneuvers. Surface impacts resulted from fluke or flipper slaps in sequences of 3-21 sounds. Source levels ranged from 162 (low-frequency pulse trains) to 192 dB (surface impacts), re: 1 μPa,1 m.

Todd S., Stevick P., Lien J., Marques F. & Ketten D. (1996) Behavioral effects of exposure to underwater explosions in humpback whales (*Megaptera novaeangliae*). *Can. J. Zool.* 74, 1661-1672
Abstract: Although explosions were characterized by high-energy signatures with principal energies under 1 kHz, humpback whales showed little behavioral reaction to the detonations in terms of decreased residency, overall movements, or general behavior. However, it appears that the increased entrapment rate may have been influenced by the long-term effects of exposure to deleterious levels of sound. A dramatic increase in the rate of humpback whales entrapment was seen, with an apparent clumping of entrapment locations. The increased sound levels or energy may be a factor in the observed changes in the distribution, resighting rate, residence, and general behavior, suggests that the animals were not reacting to the intense acoustic stimuli from the detonations. The number of animals moving toward or away from the blast area during any interval did not correlate with blasting activity in the intervening period. Furthermore, residency was high compared with that in other bays not exposed to the industrial noise. The industrial noise may have affected the hearing thresholds of humpbacks in the bay, thus decreasing their sensitivity to acoustic stimuli (the nets). The probability of an entrapment in trinity bay occurring with 2 days or less of an explosion was 0.38, which was significantly greater than the calculated rate of 0.077 for entrapments occurring outside of a 2-day lag. Dissections of the peripheral auditory systems of two whales found dead in nets demonstrated that both whales had damaged ear structures (Ketten et al. 1993; Ketten 1995), likely as a result of shock waves. In summary, it is worthwhile to reevaluate the validity of visually detectable behaviors as measures of the effects of noise. In this study we have documented that exposure to intense sound did not observably alter residency or movement of humpbacks, but appeared to affect their orientation ability.

Trites A.W. & Bain D.E. (2000) Short- and long-term effects of whale watching on killer whales (*Orcinus orca*) in British Columbia.
Abstract: Three lines of research that may shed light on long-term effects include comparative studies of populations across broad geographic ranges, assessment of physiological changes using

indicators of stress, and the development of mathematical models to evaluate possible bioenergetic consequences of whale watching. Avoiding vessels may be energetically expensive and require an animal to eat more. Maintaining vigilance against vessels may also reduce the amount of food consumed. In theory, reduced energy balance may stunt growth, delay the onset of sexual maturity and lower pregnancy rates. Sever nutritional deficiencies may even weaken an animal's immune system, increase the likelihood that chronic illnesses will become fatal, or cause death through organ failure. While collecting feces from killer whales would not be without its challenges, new techniques are being developed that may allow stress proteins to be measured in skin biopsies using molecular techniques. Stress is an important physiological state to measure given that it can potentially reduce birth rates and increase mortality.

Tyack P.L., Malme C.I., Pyle R.W., Miles P.R., Clark C.W. & Bird J.E. (1991) Reactions of migrating gray whales (*Eschrichtius robustus*) to industrial noise. Unpublished report 26 January 1991, 56p.
Keywords: GRAY WHALES/INDUSTRIAL NOISE/MIGRATION/NOISE/NOISE EFFECTS
Abstract: Environmental noise has been shown to cause the three following effects: physiological stress responses, hearing loss, and interference with normal activities. While received sound levels were not calculated, studies of both bowhead and humpback whales show avoidance of vessels at ranges near 4 km. The strongest response of whales to sound playback was a tendency to deflect away from the area of the source. In general, whales responded similarly to playback of drilling platform, drillship, helicopter, and production platform by deflecting around the source. Each stimulus except for semi-submersible evoked statistically significant responses. These results indicate that gray whales do have hearing thresholds masked by the prevailing ambient noise levels in the same frequency range as the signal. They also suggest that whales responded to some of the stimuli as soon as they were able to detect them. All of the recorded stimuli produced nearly complete avoidance at sound exposure levels of 130 dB and higher. There was significant variability in the responses of individual whales to industrial noise**.** It implies that it is necessary to study a large and unbiased sample of whales in order to assess the response characteristics of the population. Gradual habituation to repeated presentation of an otherwise neutral stimulus is a general feature of most sensory systems. However, habituation probably does not ameliorate hearing loss.

Van Parijs S.M. & Corkeron P.J. (2001) Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. *Journal of the Marine Biological Association of the United Kingdom* 81, 533-538
Keywords: Bottle-Nosed Dolphins/South-Africa/Algoa-Bay/Signature Whistles/Responses/Queensland/Population/Tourism/Waters/Cape
Abstract: In this study, the indirect (i.e. boats not involved in dolphin viewing activities) impacts of boat traffic oil the acoustic behaviour of Pacific humpback dolphins, Sousa chinensis, were assessed in Moreton Bay, Australia. Humpback dolphin acoustic behaviour is affected by transiting boat traffic. Boats' passage did not affect the rates at which dolphins produced click trains and burst pulse vocalizations. However, dolphins significantly increased their rate of whistling immediately after a boat moved through the area. This increase occurred only when boats were less than 1.5 kilometer from the groups. Groups including mother calf pairs showed all increase in whistles in response to boats' passage. Groups with no calves produced significantly fewer whistles. This evidence suggests that the noise from transiting vessels affects dolphins' group cohesion. Mother-calf pairs appear to be most disturbed by transiting vessels, and exhibit all increased need to re-establish vocal contact.

Watkins W.A. (1986) Whale reactions to human activities in Cape Cod waters. *Marine Mammal Science* 2, 251-262

Abstract: Over years of exposure to ships: minke whales have changed from frequent positive interest to generally uninterested reactions, finback whales have changed from mostly negative to uninterested reactions, right whales have apparently continued the same variety of responses with little change, and humpbacks have dramatically changed from mixed responses that were often negative to often strongly positive reactions. The primary cause of reaction was apparently underwater sound. Whales responded to acoustic stimuli within their range of hearing. Whales responded with negative (N) reactions to a wide variety of underwater sounds that appeared to be (a) unexpected, (b) too loud, (c) suddenly louder or different or (d) perceived as being associated with a potentially threatening source (such as the noise of a rapidly approaching ship or outboard on a collision course- often noticed in both finbacks and humpbacks). Such reactions were variable and depended on the whales' current activities and previous experiences. Whales that were already disturbed responded with N reactions more quickly to sounds that otherwise would have been ignored.

Watkins W.A. & Goebel C.A. (1984) Sonar observations explain behaviors noted during boat maneuvers for radio tagging of humpback whales (*Megaptera novaengliae*) in the Glacier Bay area. *Cetology* 48, 1-8
Abstract: The coincidence of occurrence of the tidal current lines with our ability to approach whales more closely was not fully recognized until we began work with the sonar. A probable consequence of the near-surface downward sound refraction (due to fresh water layer on surface) in GB would be that whales near the surface were somewhat isolated acoustically. They probably could hear sounds from more distant sources near the surface only by means of sound paths reflected from the bottom- not by direct sound paths. In addition, the heavily sedimented glacial waters would have severely limited the whales' ability to see beyond a few meters. The whales at the surface in Glacier Bay often reacted sharply when the boat would come within about 150m. It is likely that this distance was the range at which the boat sounds would have begun to be audible by direct sound paths. The close approach of whales in Icy strait for tagging were accomplished probably because of the acoustic separation provide by the different properties of the water between currents. We surmise that the acoustic properties noted (at the 60kHz sonar frequency) for the discontinuity in water masses also served to reflect or refract sound at lower frequencies. Therefore, the direct sound from the tagging boat also would not have been conspicuous to the whales until the boat moved across the line into the same water as the whales, causing the sudden reaction to the boat that we noted.

Watkins W.A. (1985) Changes observed in the reaction of whales to human activities. Report to the National Marine Fisheries Service, Contract 50-eanf-5-00068, 31p.
Keywords: DISTURBANCE/FIN WHALE/HUMAN INTERACTION/HUMPBACK WHALE/MINKE WHALE/RIGHT WHALE/WHALES
Abstract: The research vessel was gradually slowed in order to keep the underwater engine and propeller noises that were audible to the whales from increasing sharply during an approach. Sound intensity increases at a rate greater than the inverse square of the difference in distance, so that without a progressive reduction in engine speed as the vessel approached, the crescendo of noise heard by the whales would be tremendous.

Weinrich M. & Morin D. Measuring the impacts of whale-watching in New England - the history and long term view. IWC.
Abstract: In areas where whales stay in a preferred habitat over prolonged periods (e.g. preferred traditional feeding grounds for humpback whales; calving lagoons for gray whales) repeat approaches are more likely to culminate in an impact which could affect the biological fitness of the animal. Such effects could be physical (as in the potential for permanent hearing damage), physiological (by causing repeated stress responses), energetic (if an animal's behavioral

responses cause it to have a decreased ability to find food or engage in feeding behavior), or through inhibited reproduction (through inability to mate or properly tend to calves). Therefore such areas where whales do remain in limited areas for prolonged periods of time may require stricter management protocols than areas where whales pass by with little or no residency.

Williams R., Bain D.E., Ford J.K.B. & Trites A.W. (2002) Behavioural responses of male killer whales to a 'leapfrogging' vessel. *Journal of Cetacean Research and Management* 4, 305-310
Keywords: BEHAVIORAL RESPONSE/DISTURBANCE/HUMAN INTERACTIONS/KILLER WHALE/VESSEL INTERACTIONS/WHALE WATCHING
Abstract: The research and whalewatching communities of Johnstone Strait, British Columbia, Canada have worked closely together to identify whalewatching practices that minimize disturbance to northern resident killer whales. Local guidelines request that boaters approach whales no closer than 100m. Additionally, boaters are requested not to speed up when close to whales in order to place their boat in a whale's predicted path: a practice known as `leapfrogging'. A land-based study was designed to test for behavioural responses of killer whales to an experimental vessel that leapfrogged a whale's predicted path at distances greater than 100m. Ten male killer whales were repeatedly approached and the animals responded on average by adopting paths that were significantly less smooth and less straight than during preceding, control conditions. This adoption of a less `predictable' path is consistent with animals attempting to evade the approaching boat, which may have negative energetic consequences for killer whales. The results support local consensus that leapfrogging is a disruptive style of whalewatching, and should be discouraged. Similarly, as the experimental boat increased speed to overtake the whale's path, the source level of engine noise increased by 14dB. Assuming a standard spherical transmission loss model, the fast-moving boat would need to be 500m from the whale for the received sound level to be the same as that received from a slow-moving boat at 100m. Whalewatching guidelines should therefore encourage boaters to slow down around whales, and not to resume full speed while whales are within 500m.

Williams R., Trites A. & Bain D. (2001) Are killer whales habituating to boat traffic? International Whaling Commission, Scientific Committee Document SC/53/WW3, 10p.
Keywords: BRITISH COLUMBIA/ECOTOURISM/HABITUATION/HUMAN INTERACTIONS/KILLER WHALE/NOISE/WASHINGTON STATE/WHALE WATCHING
Abstract: There is a discrepancy between the results of Williams et al. (2001) and Kruse (1991). Kruse found that whale swim speed increased as number of boats increased, and Williams et al. (2001) found no evidence of this. In fact, as more boats approached male killer whales in 1995-96, swim speeds actually decreased. The discrepancy may be explained by differences in study design or analysis but it may also reflect a change of whale behavior around boats over time. If the discrepancy between these studies is real, then this would provide evidence that these whales can tolerate boat traffic that they initially found disruptive. Habituation may then temper our ability to measure disturbance, but not eliminate the disturbance itself. This underscores the importance of measuring impact when, or ideally before, ecotourism ventures begin in a new area. Overall, these analyses indicate that northern resident killer whales respond to boat traffic using a variety of horizontal avoidance tactics that may be viewed as adopting a less _'predictable' surfacing pattern. The whales appear not to have changed the nature of that response between 1985 and 1998. However, they appear to have reduced the intensity of that response. So far, our findings appear to be most consistent with partial habituation to boats.

Williams R., Trites A.W. & Bain D.E. (2002) Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology, London* 256 , 255-270
Keywords: BEHAVIOR/BEHAVIORAL RESPONSE/BRITISH

COLUMBIA/DISTURBANCE/JOHNSTONE STRAIT/KILLER WHALE/VESSEL INTERACTIONS /WHALE WATCHING
Abstract: Observations were land-based and they used control, experimental and opportunistic tracks. When approached by the experimental boat, the paths of male whales became less direct than during the preceding control conditions. Thus, the average male responded to the experimental boat by covering 13% more distance along a circuitous path than it covered before the boat arrived. No significant changes in dive time, swim speed, deviation index, or rate of surface-active behavior were observed. Significant behavioral variables for male whales were swimming speed, directness index, and rate of surface-active behavior. When approached by experimental boat, female whales responded by swimming 25% faster and increasing the mean angle deviation between surfacing by 29%. No significant changes in means dive time, directness index or rate of surface-active behavior were observed. Basically, paths of males tended to be less direct as boats got closer but more direct when the number of whale-oriented boats increased. Whales tended to swim faster as boats got closer, and to slow down as number of boats increased. Rates of surface-active behaviors decreased as boats moved closer to the whales, but increased as the number of whale-oriented vessels increased. Trends are further compounded by age-related behavior differences of whales and seasonal components.

Wright M. (1998) Ecotourism on Otago Peninsula: preliminary studies of yellow-eyed penguin *(Megadyptes antipodes)* and Hooker's sea lion *(Phocarctos hookeri)*. Department of Conservation, Wellington, New Zealand.
Keywords: ECOTOURISM/HOOKER'S SEA LION/HUMAN INTERACTIONS/NEW ZEALAND/OTAGO PENINSULA/PENGUIN (YELLOW-EYED)
Abstract: Sea lions were approached while hauled out on the beach to a distance of 5, 10 or 20m. The study found no difference in sea lion behavior when approached 5, 10 or 20m, regardless of whether they were solitary animals or part of group. In the 18 months prior to this study, researchers regularly went up close to sea lions and occasionally lifted their flippers in order to see the ID marks. This indicates increased tolerance and habituation of the sea lions to people.

Wursig B. & Greene C.R. (2002) Underwater Sounds Near a Fuel Receiving Facility in Western Hong Kong: Relevance to Dolphins. *Marine Environmental Research* 54, 129-145
Keywords: Underwater Sounds/Noise/Tankers/Mammals/Marine Mammals/Ecosystem Disturbance/Disturbance/Environmental Impact/Indo-Pacific Humpbacked Dolphin Sousa Chinensis/Finless Porpoise, Neophocaena Phocaenoides
Abstract: Western Hong Kong is home to two species of marine mammals: Indo-Pacific humpbacked dolphins (*Sousa chincnsis*) and finless porpoises (*Neophocaena phocaenoides*). Both are threatened in many parts of their range in southeast Asia [for example, International Biological Research Institute Reports 9 (1997). 41, Asian Marine Biology 14 (1997) 111]. In 1998, when the new Hong Kong International Airport opened in western Hong Kong. small tankers (about 100 m long, cargo capacity about 6300 metric tons) began delivering fuel to the Aviation Fuel Receiving Facility (AFRF)just off Sha Chau Island. north of the airport. Calibrated sound recordings were taken over a 4-day period from a quiet, anchored boat at distances 80 2000 m from aviation fuel delivery activities at the AFRF. From the recordings, 143 sections were selected for analysis, Narrowband spectral densities on the sound pressures were computed, and one-third octave band levels were derived for center frequencies from 10 to 16,000 Hz. Broadband levels, viz. 10-20,000 Hz. were also computed. The results showed that the Sha Chan area is normally noisy underwater, with the lowest broadband levels measured corresponding to those expected during a storm at sea (sea state 6). This background noise is believed to come largely from heavy vessel traffic in the Urmston Road to the north and east of Sha Chau and front vessels in the Pearl River Estuary to the West, The sound levels from the AFRF tankers are comparable to the levels measured from similar- and smaller-sized supply vessels supporting

offshore oil exploration. The strongest sounds recorded were from a tanker leaving the AFRF at distance 100 m from the hydrophone, for which the one-third octave band level at 100 Hz was 141 dB re 1 muPa (spectrum level 127 dB re 1 muPa(2)/Hz) and the 10-20,000 Hz broadband level was 146 dB. At distances of 100 m or more and frequencies above 300 Hz, the one-third octave band levels were less than 130 dB (spectrum level 111 dB re 1 muPa(2)/Hz) and decreased with increasing frequency and distance. At distances greater than about 500 m. AFRF-associated sounds were negligible, masked by the generally high noise level of the area and attenuated by poor transmission in the very shallow water (< 10 m). Because it is believed that humpbacked dolphins and finless porpoises are not very sensitive to sounds below 300 Hz, the Airport Authority Hong Kong (AA) stipulated that dedicated terminal vessels not radiate underwater sounds at spectrum levels greater than 110 dB re 1 muPa(2)/Hz at frequencies above 300 Hz and distances greater than 300 m. The spectrum levels at 300 Hz and higher frequencies of sounds from the tankers arriving. departing, or off-loading at AFRF were less than 110 dB re 1 muPa(2)/Hz even at distances of 200 in or less. The AA stipulation was met. However, it is presently unknown whether the generally strong noise levels of western Hong Kong inhibit acoustically based feeding and communication. or result in increased stress or permanent shifts in hearing, thresholds.

Wursig B., Greene C.R. & Jefferson T.A. (2000) Development of an Air Bubble Curtain to Reduce Underwater Noise of Percussive Piling. *Marine Environmental Research* 49, 79-93
Keywords: Sounds/Attenuation/Bubble Curtain/Bubble Screening/Dolphins/Sousa Chinensis/Environment/Mitigation/Noise/Pile Driving
Abstract: Underwater bubbles can inhibit sound transmission through water due to density mismatch and concomitant reflection and absorption of sound waves. For the present study, a perforated rubber hose was used to produce a bubble curtain, or screen, around pile-driving activity in 6-8-m depth waters of western Hong Kong. The percussive hammer blow sounds of the pile driver were measured on 2 days at distances of 250, 500, and 1000 m; broadband pulse levels were reduced by 3-5 dB by the bubble curtain. Sound intensities were measured from 100 Hz to 25.6 kHz, and greatest sound reduction by the bubble curtain was evident from 400 to 6400 Hz. Indo-Pacific hump-backed dolphins (Sousa chinensis) occurred in the immediate area of the industrial activity before and during pile driving, but with a lower abundance immediately after it. While hump-backed dolphins generally showed no overt behavioral changes with and without pile driving, their speeds of travel increased during pile driving, indicating that bubble screening did not eliminate all behavioral responses to the loud noise. Because the bubble curtain effectively lowered sound levels within 1 km of the activity, the experiment and its application during construction represented a success, and this measure should be considered for other appropriate areas with high industrial noises and resident or migrating sound-sensitive animals.

Würsig B., Lynn S.K., Jefferson T.A. & Mullin K.D. (1988) Behavior of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquatic Mammals.* 24, 41-50
Abstract: *Kogia* spp. and ziphiids showed the most avoidance reactions towards ships (73%), with large delphinids at 15%, small delphinids at 6%, and *Stenella frontalis* and *Tursiops truncatus* as 0% each. *S. coeruleoalba* move to avoid the ships in 33% of sightings. Species that responded to the ships (either approaching or avoiding) also changed behavior in response to the survey airplane. For all cetacean species, the behavioral states _'milling' and _'resting' appeared to be sensitive to disturbance; over 39% of initial observations of these behaviors were followed by a new behavior. Our impression was that differences among vessels, if they exist, were much smaller than differences among species and species categories. Behavior is even more variable than discussed in this paper, with potential differences by school size, age and sex, time of day, season, weather, and other factors. Dusky dolphins (*Lagenorhynchus obscurus*) of the southern

hemisphere show marked differences in human interaction response relative to age and sex and to seasonality.

Relevancy Table for Annotated References – Marine Mammals

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Acevedo, A.	No: dolphins	No: Mexico	No: all boats	B	3
Akamatsu et al.	Yes: false killer whales	No: captive	N/A	B	1
Akamatsu et al.	Yes: Steller sea lions	No: captive	N/A	B	2
Allen and Read	No: dolphins	No: Florida	No: all boats	B	1
Allen et al.	Yes: harbor seals	No: California	No: all boats	B	1
Ananthaswamy, A.	N/A	N/A	N/A	N/A	N/A
Anderson, I.	N/A	N/A	N/A	N/A	N/A
Au et al.	Yes: belugas	No: Hawaii	N/A	B	2
Au and Green	Yes: humpbacks	No: Hawaii	No: whale watch	B	1
Au and Perryman	No: dolphins	No: E. Pacific	Yes: survey ship	B	4
Australia and NZ ECC	N/A	N/A	N/A	N/A	N/A
Bain and Dahlheim	Yes: killer whales	No: captive	N/A	B	1
Baker and Herman	Yes: humpbacks	Yes: Alaska	No: all boats	B	1
Baker et al. 1982	Yes: humpbacks	Yes: Alaska	No: all boats	B	1
Baker et al. 1983	Yes: humpbacks	Yes: Alaska	No: all boats	B	1
Barr, K.	No: dolphins	No: New Zealand	No: all boats	B	1
Bauer, G.	Yes: humpbacks	No: Hawaii	No: all boats	B	3
Bauer and Herman	Yes: humpbacks	No: Hawaii	No: all boats	B	3
Beach and Weinrich	N/A	N/A	N/A	N/A	N/A
Bejder et al.	No: dolphins	No: New Zealand	No: all boats	B	1
Bejder and Samuels	N/A	N/A	N/A	N/A	N/A
Blane and Jaakson	Yes: belugas	No: Canada	No: all boats	B	4
Borggaard et al.	Yes: large cetaceans	No: Newfoundland	No: industrial boats	B, P, D	1
Born et al.	Yes: ringed seals	No: Greenland	No: aircraft	B	3
Bowles et al.	Yes: cetaceans	No: Indian Ocean	N/A	B	1

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Buckingham et al.	No: manatee	No: Florida	No: all boats	B	3
Buckstaff, K.	No: dolphins	No: Florida	No: all boats	B	1
Burgess et al.	Yes: elephant seals	No: California	N/A	B	4
Calambokidis et al.	Yes: harbor seals	No: Washington	No: all boats	B	3
Cassini, M.	Yes: fur seals	No: Uruguay	N/A	B	4
Cessford, G.	N/A	N/A	N/A	N/A	N/A
Cessford and Dingwall	N/A	N/A	N/A	N/A	N/A
Clapham and Mattila	Yes: humpbacks	No: West Indies	No: research boat	B	1
Constantine et al.	No: dolphins	No: New Zealand	No: whale watch	B	3
Corkeron, P.	N/A	N/A	N/A	N/A	N/A
Corkeron, P.	Yes: humpbacks	No: Australia	No: whale watch	B	1
Coscarella et al.	No: dolphins	No: Patagonia	No: whale watch	B	3
Costa et al.	Yes: elephant seals	No: California	N/A	B	1
Doherty and Gabriele, 2004	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Doherty and Gabriele, 2003	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Doherty and Gabriele, 2002	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Doherty and Gabriele, 2001	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Duffus and Dearden	Yes: killer whales	No: Canada	N/A	N/A	4
Edds and Macfarlane	Yes: baleen whales	No: Canada	Yes: ferry No: small boat	B	4
Engelhard et al.	Yes: elephant seal	No: Australia	N/A	B	1
Erbe, C.	Yes: killer whales	No: Washington	N/A	N/A	N/A
Erbe, C. 2003	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	N/A
Erbe, C. 2002	Yes: killer whales	N/A	N/A	N/A	N/A

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Evans et al.	No: dolphins	No: West Wales	No: small boats	B	2
Findlay, K.	N/A	N/A	N/A	N/A	N/A
Finley et al.	Yes: belugas No: narwhals	No: Canada	No: icebreakers	B	1
Foote et al.	Yes: killer whales	No: Washington	N/A	B	1
Frankel and Clark, 2002	Yes: humpbacks	No: Hawaii	N/A	B	1
Frankel and Clark, 2000	Yes: humpbacks	No: Hawaii	N/A	B	1
Frankel and Clark, 1998	Yes: humpbacks	No: Hawaii	N/A	B	1
Freddy et al.	No: mule deer	No: Colorado	N/A	B	1
Frid and Dill	N/A	N/A	N/A	N/A	N/A
Gabriele and Doherty	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Gabriele et al. 1999	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Gabriele et al. 1997	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Gabriele and Hart	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	4
Gabriele and Lewis	Yes: marine mammals	Yes: Glacier Bay	N/A	N/A	3
Gill et al.	N/A	N/A	N/A	N/A	3
Glockner-Ferrari and Ferrari	Yes: humpback	No: Hawaii	N/A	B	4
Goodwin and Cotton	No: dolphins	No: UK	No: all boats	B	3
Gordon and Moscrop	N/A	N/A	N/A	N/A	N/A
Hall, J.	Yes: humpbacks	Yes: PWS, Alaska	No: research vessel	B	4
Harwood, J.	N/A	N/A	N/A	N/A	N/A
Hastie et al.	No: dolphins	No: Scotland	No: all boats	B	3
Heckel et al.	Yes: gray whales	No: California	No: whale watch	B	1

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Henry and Hammill	Yes: harbor seals	No: Canada	No: small boats	B	3
Hewitt, R.	No: dolphins	Unknown	Yes: survey vessel	B	4
Hill et al.	No: birds	N/A	N/A	N/A	N/A
Janik and Thompson	No: dolphins	No: Scotland	No: all boats	B	1
Jansen et al.	Yes: harbor seals	Yes: Disenchantment Bay, Alaska	Yes: cruiseships	B	3
Jensen and Silber	N/A	N/A	N/A	N/A	N/A
Johnson, D.	N/A	N/A	N/A	N/A	N/A
Johnson and Tyack	Yes: right whales Yes: sperm whales	No: Mexico, Canada, Ligurian Sea	N/A	B	1
Johnston, M.	N/A	N/A	N/A	N/A	N/A
Jurasz and Palmer, 1981a	Yes: humpbacks	Yes: Glacier Bay	N/A	B	4
Jurasz and Palmer, 1981a	Yes: humpbacks	Yes: Glacier Bay	No: all boats	B	4
Kastak et al.	Yes: pinnipeds	No: captive	N/A	B, P	1
King and Heinen.	No: manatees				
Kipple, B. 2002a	N/A	N/A	N/A	N/A	N/A
Kipple, B. 2002b	N/A	N/A	N/A	N/A	N/A
Kipple and Gabriele, 2004	N/A	N/A	N/A	N/A	N/A
Kipple and Gabriele, 2003a	N/A	N/A	N/A	N/A	N/A
Kipple and Gabriele, 2003b	N/A	N/A	N/A	N/A	N/A
Koehler, N.	Yes: humpbacks	Yes: Point Adolphus	N/A	N/A	4
Kovacs and Innes	Yes: harp seals	No: Canada	N/A	B	1
Kruse, S.	Yes: killer whales	No: Canada	No: all boats	B	1
Laist et al.	N/A	N/A	N/A	N/A	N/A
Leatherwood et al.	Yes: minke whales	No: Ross Sea	No: icebreaker	B	4

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Lesage et al.	Yes: belugas	No: Canada	Yes: ferry No: small boat	B	1
Lewis and Mathews	Yes: harbor seals	Yes: Glacier Bay	No: all boats	B	4
Ljungblad et al.	No: bowheads	No: Alaskan Beaufort Sea	No: active geophysical vessel	B	1
Lusseau, D. 2004	No: dolphins	No: New Zealand	No: all boats	B	1
Lusseau, D. 2003a	No: dolphins	No: New Zealand	No: all boats	B	1
Lusseau, D. 2003b	No: dolphins	No: New Zealand	No: all boats	B	1
Lusseau and Higham	No: dolphins	No: New Zealand	N/A	N/A	3
MacArthur et al. 1982	No: sheep	No: Canada	N/A	B, P	1
MacArthur et al. 1979	No: sheep	No: Canada	N/A	B, P	1
Magalhães et al.	Yes: sperm whales	No: Azores	No: whale watch	B	1
Malme, C.	Yes: gray whales	Unknown	No: drillships	B	1
Malme and Miles	N/A	N/A	N/A	N/A	N/A
Malme et al. 1984	Yes: gray whales	Unknown	N/A	B	1
Malme et al. 1983	Yes: gray whales	Unknown	N/A	B	1
Malme et al. 1982	Yes: humpbacks	Yes: Glacier Bay	N/A	N/A	N/A
Malme et al. 1988	Yes: gray whales	Unknown	N/A	B	1
Mathews, E. 2000a	Yes: sea lions	Yes: Glacier Bay	No: all boats	B	1
Mathews, E. 2000b	Yes: harbor seals	Yes: Glacier Bay	No: all boats	B	4
Mathews, E. 1997	Yes: harbor seals	Yes: Glacier Bay	N/A	B	4
Mathews, E. 1994	Yes: harbor seals	Yes: Glacier Bay	Yes: Cruiseships No: seismic vessel	B	4

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Mathews and Driscoll	Yes: harbor seals	Yes: Glacier Bay	No: all boats	B	1
Mathews and Pendleton	Yes: harbor seals	Yes: Glacier Bay	N/A	N/A	4
Miller et al.	No: bowheads	No: Bering/Beaufort Sea/Davis Strait	N/A	N/A	N/A
Mobley, J.	Yes: humpbacks	No: Hawaii	N/A	B	1
Mobley et al.	Yes: humpbacks	No: Hawaii	N/A	B	1
Moore and Clarke	Yes: gray whales	No: California	N/A	N/A	N/A
Nishiwaki and Sasao	Yes: minkes, Bairds beaked whales	Unknown	No: all boats	B	4
Nowacek et al. 2004	No: manatees	No: Florida	No: all boats	B	1
Nowacek et al. 2001	No: dolphins	No: Florida	No: all boats	B	1
National Research Council	N/A	N/A	N/A	N/A	N/A
Ng, S. L., and S. Leung.	No: dolphin	No: Hong Kong	No: all boats	B	3
Orams, M.	N/A	N/A	N/A	N/A	N/A
Patenaude et al.	Yes: belugas No: bowheads	No: Alaskan Beaufort	N/A	B	4
Polacheck and Thorpe	Yes: harbor porpoise	No: Canada	Yes: survey vessel	B	3
Rendell and Gordon	Yes: pilot whales	No: Ligurian Sea	N/A	B	4
Richardson, W. (eds.), 1999	Yes: seals, gray whales No: bowheads	No: Alaskan Beaufort	N/A	B	1
Richardson, W. 1993	Yes: belugas No: bowheads	No: Point Barrow, Alaska	N/A	B	3
Richardson et al. 1987	No: bowheads	No: Canadian Beaufort Sea	No: active industrial ships	B	3
Richardson et al. 1995	No: bowheads	No: Baffin/Beaufort	N/A	B	3

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Richardson and Fraker	No: bowheads	No: Beaufort Sea	No: active industrial ships	B	1
Richardson et al.	Yes: belugas No: bowheads	No: Point Barrow, Alaska	No: active industrial ships	B	1
Richardson and Malme.	N/A	N/A	N/A	N/A	N/A
Richardson and Würsig.	N/A	N/A	N/A	N/A	N/A
Richardson et al. 1990	No: bowheads	No: Canadian Beaufort Sea	No: active industrial ships	B	1
Richardson et al. 1986	No: bowheads	No: Canadian Beaufort Sea	No: seismic vessels	B	1
Richter et al.	N/A	N/A	N/A	N/A	N/A
Salden, D.	Yes: humpbacks	No: Hawaii	N/A	B	4
Scarpaci et al.	No: dolphins	No: Australia	No: whale watch	B	1
Scheidat et al.	Yes: humpbacks	No: Ecuador	No: whale watch	B	1
Smethurst and Nietschmann	No: manatees	No: Costa Rica	No: all boats	B	4
St. Aubin and Dierauf	N/A	N/A	N/A	N/A	N/A
Suryan and Harvey	Yes: harbor seals	No: Washington	No: all boats	B	1
Taylor and Dawson	Yes: harbor porpoise	Yes: Glacier Bay	No: all boats	B	4
Thomas et al.	Yes: belugas	No: captive	N/A	B, P	1
Thompson et al.	Yes: humpbacks	Yes: SE Alaska	N/A	N/A	4
Todd et al.	Yes: humpbacks	No: Newfoundland	N/A	B, P, D	1
Trites and Bain	Yes: killer whales	No: Canada	N/A	N/A	N/A
Tyack et al.	Yes: gray whales	Unknown	N/A	B	1
Van Parijs and Corkeron	No: dolphins	No: Australia	No: all boats	B	1
Watkins, W. 1985	Yes: baleen whales	No: NE Atlantic	No: all boats	B	4
Watkins, W. 1986	Yes: baleen whales	No: NE Atlantic	No: all boats	B	4

Study	Common species	Location	Vessel Behavior	Affect B, P or D*	Rigor Score**
Watkins and Goebel	Yes: humpbacks	Yes: Glacier Bay	No: research boat	B	1
Weinrich and Morin	N/A	N/A	N/A	N/A	N/A
Williams et al. 2002	Yes: killer whales	No: Canada	No: whale watch	B	1
Williams et al. 2002	Yes: killer whales	No: Canada	No: whale watch	B	1
Williams et al. 2001	Yes: killer whales	No: Canada	No: whale watch	B	3
Wright, M.	No: Hooker's sea lion	No: Otago Peninsula	N/A	B	1
Würsig et al. 2000	No: dolphins	No: Hong Kong	N/A	B	1
Würsig et al. 1998	Yes: cetaceans	No: Gulf of Mexico	Yes: survey ship	B	4

***** Affects behavior (B), physiology (P) or demographics (D)

** ** Rigor Score is an index of study design rigor, using a scale of 1(very rigorous) to 4(observational), as defined by Hill et al. 1997.

Appendix D:

Potential Disturbance of Marine Birds from Cruise Ships

Potential Impacts of Cruise Ships on the Marine Birds of Glacier Bay

Literature Review Prepared for the
Glacier Bay National Park and Preserve
Vessel Management Science Advisory Board

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General Considerations

Vessel disturbance of avian species has received research attention of numerous avian species, in many locations across the world's water systems (Boyle and Samson 1985, Hockin et al. 1992, Hill et al. 1997, Nisbet 2000). Although the breadth of research on vessel disturbance of birds is great, issues of study design quality, location variability, species-specific response patterns, and a lack of consistent reporting of variables influencing vessel disturbance all complicate the comparison of study results (see attached Relevancy Table). Critical evaluation of peer-reviewed literature provides a summary of the current state of knowledge regarding vessel disturbance impacts on avian species, highlights critical gaps in knowledge, and prioritizes suggested research in Glacier Bay National Park and Preserve.

Trends in avian response to vessel disturbance that emerge from evaluation of the literature:

1) Birds generally alter behavior in response to visual stimulus of vessel presence.

2) Avian response to vessel presence is species-specific.

3) The distance between a bird and vessel, or the 'approach distance', generally influences avian response (with closer approaches generally equating to greater probability of response).

4) Vessel speed affects the response of birds to vessel disturbance, such that higher speed generally results in greater probability of flight response.

5) Habituation of bird species to vessel disturbance activity has occurred, but varies by species and habitat type.

Critical Gaps in Knowledge and Prioritization of Suggested Research

The current knowledge base of literature on vessel disturbance impacts to avian species is largely inapplicable to conditions in Glacier Bay and specifically to the case of cruise ship disturbance. Peer-reviewed literature to date has not reported the effects of cruise

ships on avian species. For this reason, discussion of the potential impacts of cruise ships should be regarded as hypothetical, albeit informed by patterns in avian response to vessels from existing study. Additionally, only one peer-reviewed study of vessel disturbance of birds has been conducted in an environment similar to Glacier Bay (Prince William Sound, AK: Kuletz 1996: *Relevance Score = 2; Rigor Score = 4*). As avian response to vessel disturbance is found to be species-specific, it is also important to note that many studies to date have focused on bird species which are not found in Glacier Bay.

Given these considerations, the following research prioritization is suggested.

1) Focus research efforts on species of concern, endangerment, or species which are most likely to encounter cruise ship traffic (suggested focal species include: Kittlitz's Murrelet, Marbled Murrelet, Pigeon Guillemot, Surf Scoter, White-Winged Scoter).
2) Consider study of cruise ship disturbance of suggested focal species with specific implications for life stages of high potential for resultant impact, such as physiologically demanding life stages including chick rearing (Mikola et al. 1994), migration (Schummer and Eddleman 2003; Knapton et al. 2000, Havera et al. 1992, Kahl 1991), and molting (Miller et al. 1994). Chick provisioning may be another important life stage to consider; however, there currently are no studies which focus of impacts specific to this life stage.
3) Study suggested focal species behavior before, during, and after cruise ship disturbance at sites frequented by cruise ship traffic. Compare to behavior of focal species at 'control' sites, without cruise ship traffic (e.g. of study design: Lacroix et al. 2003). To ensure comparability, impact and control sites should be observed simultaneously, should have the same level of other vessel traffic, and should be relatively close in proximity.
4) Use behavioral study results to produce time budgets per behavior before, during and after disturbance. Compare time budgets between control and impact sites. Additionally, convert time budgets to energy budgets (time to kJ), and compare energy budgets during disturbance at the impact site to energy budgets at the control site. Calculate the rate of energy expenditure per cruise ship event by evaluating the difference in energy expenditure between control and impact sites per event. Consider alternative scenarios of cruise ship traffic, and evaluate the species impact in terms of energetic cost (e.g. of behavior modeling: West et al. 2002, Sutherland 1996, Miller et al. 1994).

Of further importance, many biological variables have been found to influence the response of birds to vessel disturbance. For instance, avian response to vessel disturbance is species-specific, evident by a number of studies (n=11) that investigate the response of multiple species within the same study context (Traut and Hostelter 2003; Rodgers and Schwikert 2003; Rodgers and Schwikert 2002; Ward et al. 1999; Conomy et al. 1998; Rodgers and Smith 1997; Rodgers and Smith 1995; Reijnen et al. 1995; Pierce et al. 1993; Bamford et al. 1990; Bratton 1990). Additionally, bird age (Rodgers and Smith 1995), breeding stage (Delaney et al. 1999; Burger 1998), breeding status (Rodgers

and Schwikert 2002), and season of year (Bamford et al. 1990; Pierce et al. 1993; Robinson and Politt 2002) are all biological factors that have been found to significantly influence the response of avian species to vessel disturbance. Thus, such factors should be addressed in future research.

Likewise, a number of environmental variables have the potential to influence bird response to vessel disturbance. Weather (Burger and Galli 1987, Schueck and Marzluff 1995), tide related parameters (Keller 1991; Burger and Galli 1987), habitat type (Kaiser and Fritzell 1984; Bratton 1990; Pierce et al. 1993), and time of day (Bamford et al. 1990) were found to influence the response of avian species to vessel disturbance. Thus, these factors should also be addressed in future research.

Variables specific to the actual vessel under consideration as a disturbance mechanism, such as vessel speed (Burger 1998; Pierce et al. 1993; Keller 1991; Ronconi and St Clair 2002), vessel size (Ronconi and St Clair 2002), and approach distance (Delaney et al. 1999; Rodgers and Schrikert 2003; Rodgers and Smith 1997; Rodgers and Smith 1995; Ronconi and St Clair 2002) have also been influential in determining the response of avian species to vessel disturbance. Inclusion of vessel related variables will be important for future research.

Summary of Impacts by Category

A. Visual Disturbance

Impact caused by vessel disturbance is considered direct when measured or modeled species response to disturbance directly impairs species fitness (reproduction and survival), and indirect when species response to disturbance significantly hinders activities of importance to fitness (e.g. diminished body condition). Literature on vessel disturbance of avian species is almost entirely focused on visual disturbance, or disturbance caused by the visual stimulus of vessel presence. This body of literature has developed due to management needs that include development of buffer zones to effectively isolate birds from vessel disturbance, and quantification of the impact of recreational use on avian species to allow for evaluation of recreational use levels.

i) Behavioral impacts

Studies have documented a variety of avian behavioral responses to vessel disturbance which includes altered behavior states, and change in social structure. The visual disturbance of vessel presence has been shown to cause increased alert behavior (Bamford et al. 1990; Galicia and Baldssarre 1991; and Traut and Hosteler 2003), flight (Belanger and Bedard 1998; Bratton 1990; Havera et al. 1992; Hume 1976; Kahl 1991; Kenow et al. 2003; Knapton et al. 2000; Korschgen et al. 1985; Pierce et al. 1993; Traut and Hosteler 2003), swimming (Kenow et al. 2003), and a reduction in foraging (Kaiser and Fritzell 1984; Knight and Knight 1984; Stolen 2003; and Galicia and Baldssarre 1997).

In one study, social structure of duck broods changed in the presence of vessels, such that broods scattered (Keller 1991). Two studies show that habituation, or a resultant stabilization of response over exposure time, of birds to vessel disturbance is possible (Stolen 2003; Burger and Galli 1987). Studies to date rarely model the potential impact of behavioral changes in a biologically meaningful way, making extrapolation of the potential impacts of such results difficult.

ii) Physiological impacts

The physiological response of avian species to visual disturbance caused by vessels has not been investigated to date. However, it is important to note that instantaneous physiological measures may be a better indicator of bird response to stimulus from vessel disturbance than visual observation. Knowledge of physiology will improve the ability to estimate energetic cost associated with vessel disturbance. Instantaneous physiological measures are retrievable from individual birds via radio telemetry technology (e.g. Ely et al. 1999).

iii) Demographic impacts

Few studies investigate the demographic impacts of avian response to visual disturbance of vessel presence; however, those which do conclude demographic impacts include increased potential for predator encounters with offspring (Keller 1991), and increased mortality of offspring (Mikola et al. 1994). Less severe demographic consequences range from delayed arrival at breeding grounds due to increased foraging requirements (higher energy cost to avoid vessels) at migratory stopover sites (Schummer and Eddleman 2003), and a reduction in bird use of vessel disturbed locations, measured as reduced abundance (Bamford et al 1990; Kaiser and Fritzell 1984; Kuletz 1996). Although demographic impacts have been quantified, by and large very little effort has been made to model the sub-population or population level impact of vessel disturbance consequences for species investigated.

B. Sound Disturbance

Although only one study to date investigates the potential impact of vessel sound on avian response, a number of studies provide insight to the effect of sound from other mechanized transportation modes (cars, airplanes, helicopters). Evaluating the findings from current literature on avian response to sound disturbance provides generalized knowledge which may be useful to structuring future work addressing the potential impact of sound disturbance from cruise ships on avian species. This body of literature has developed out of a management need to ensure that human activities are not significantly impacting avian species.

i) Behavioral impacts

Sound disturbance has been shown to cause varied behavioral response ranging from lack of response, to altered behavior states. Habituation of birds to sound disturbance was

detected in two studies (Delaney et al. 1999; Conomy et al. 1998), and lack of response was detected in another study, by finding a non-significance of change in diving intensity between the presence and absence of sound disturbance (Lacroix et al. 2003). Although, other study concludes that behavior state changes in the presence of sound disturbance, such that the bird species investigated flew (Brown 1990; Ward et al. 1999; Burger 1998) and became alert (Conomy et al. 1998; Grubb and King 1991) in the presence of sound disturbance.

ii) Physiological impacts

The physiological response of avian species to sound disturbance has not been investigated to date.

iii) Demographic impacts

Sound disturbance has rarely been investigated in a demographic context, but where the ability to evaluate demographic impacts exists in the literature, results vary. The most severe demographic impact of sound disturbance to an avian species measured to date is reduction of breeding density (Reijnen et al. 1995); although, a different study concludes that sound disturbance does not affect reproductive success or productivity (Delany et al. 1999). Another study concludes that sound disturbance causes reduction in bird abundance (Batten 1977); however, the converse has also been concluded (Lacroix et al. 2003), whereby sound disturbance was not found to significantly influence bird abundance.

Summary of Impacts to Marine Bird Species

Few studies have demonstrated impact of vessel disturbance to marine bird species; however, both direct and indirect impacts have been identified.

1) A direct impact on offspring survival when vessels travel in proximity to swimming duck broods. Broods respond by scattering, increasing vulnerability to predation encounters (Keller 1991), and resulting in higher incidence of offspring mortality (Mikola et al. 1994).
2) A reduction in foraging behavior and an increase in energetically costly behavior, such as flight. Behavior changes can constitute energetic impact at high rates of vessel traffic (Schummer and Eddleman 2003: *Relevance−0, Rigor−1*, Korschgen et al. 1985: *Relevance−1, Rigor−4*).
3) A loss of suitable habitat, as vessel traffic has been shown to reduce bird use of vessel disturbed areas (Bamford et al 1990: *Relevance−0, Rigor−4*, Kaiser and Fritzell 1984: *Relevance−0, Rigor−2*, and Kuletz 1996: *Relevance−2, Rigor−4*).

Although some studies suggest that vessels have the potential to impact colony nesting birds by increasing the potential for nest predation, nest abandonment, and/or premature fledge (Burger 1998; Rodgers and Smith 1995), cruise ships in Glacier Bay do not pass directly near many of the colonies of nesting birds. Thus impacts to nesting success will

probably be minimal. Additionally, although some studies suggest that suitable habitat may be lost due to reduced bird use of vessel disturbed areas (summary point 3), there is a great expanse of area in Glacier Bay that is not exposed to cruise ship traffic. Therefore, it is unlikely that a reduction in bird use of specific areas utilized by cruise ships should constitute a loss of suitable habitat. Further, it is commonly the case in Glacier Bay that avian species which rear offspring in broods do so in the shelter of near shore waters. Thus, it is unlikely that cruise ships will cause disturbance to broods, as cruise ships remain mid-channel throughout Glacier Bay. Demographic effects from altered adult foraging patterns are more likely in Glacier Bay for avian species which normally forage in areas frequented by cruise ships.

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Relevancy Table for Annotated References – Marine Birds

Study Year	Common Species	Location	Vessel behavior	Relevance Score*	Rigor Score**
Bamford et al. 1990	No: 27 species not found or common in Glacier Bay	No: Perth, Australia	No: model powerboat	0	4
Batten 1977	Yes: Herring Gull	No: Brent Reservoir, Northwest London	No: sailboat	1	4
Belanger and Bedard 1989	No: Greater Snow Geese	No: Montmagny Sanctuary, Quebec	Yes: ferry boat	1	4
Bratton. 1990	Yes: Great Blue Heron	No: Cumberland Sound, Georgia	No: motorboat	1	4
Brown 1990	No: Crested Tern	No: Great Barrier Reef, Australia	No: simulated floatplane noise	0	1
Burger 1998	No: Common Tern	No: Barnegat Bay, New Jersey	No: jet-ski and powerboat	0	1
Burger and Galli 1987	Yes: Herring Gull	No: Coastal New Jersey	No: 'boat', type not specified	1	4
Conomy et al. 1998	No: Black Duck and Wood Duck	No: Coastal North Carolina	No: airplane noise simulation	0	1
Delaney et al. 1999	No: Mexican Spotted Owl	No: South Central New Mexico	No: helicopter	0	1
Galicia. and Baldassarre 1997	No: American Flamingo	No: Celestun Estuary, Yucatan Peninsula of Mexico	No: tour boat of unknown size	0	1
Grubb and King 1991	Yes: Bald Eagle	No: Central Arizona	No: canoe, kayak and motorboat	1	3
Havera et al. 1992	No: Lesser Scaup, Canvasback, American Coot	No: Keokuk Pool, Upper Mississippi River	Yes: Barge (motorboat investigated as well)	1	4
Hume 1976	No: Common Goldeneye	No: Staffordshire, England	No: powerboat	0	4
Kahl 1991	No: Canvasback	No: Lake Poygan, Central Wisconsin	No: powerboat	0	4
Kaiser. and Fritzell 1984	No: Green-Backed Heron	No: Southeastern Missouri	No: canoe, powerboat, innertubes	0	2
Keller 1991	No: Mexican Spotted Owl	No: North Scotland	No: small powerboat, rowboat and windsurfing	0	1

Study Year	Common Species	Location	Vessel behavior	Relevance Score*	Rigor Score**
Kenow et al. 2003	Yes: Mallard (other waterfowl investigated not found or common in GBNP)	No: Upper Mississippi River, Wisconsin	Yes: commercial fishing boat (canoeing, motorboating, sailing investigated as well)	2	4
Knapton et al. 2000	No: Canvasback, Redheads, Scaup spp.	No: Long Point Bay, Lake Erie, Ontario, Canada	Yes: commercial fishing boat (powerboats also investigated)	1	4
Knight. and Knight 1984	Yes: Bald Eagle	No: Northwestern Washington	No: canoe, raft, and motorboat	1	2
Korschgen et al. 1985	Yes: Common Merganser (however most of study focused on three species- Canvasback, Lesser Scaup, and Ring-necked duck	No: Lake Onakaska, Upper Mississippi River	No: motorboat	1	4
Kuletz 1996	Yes: Marbled Murrelet	Yes: Prince William Sound, Alaska	No: motorboat	2	4
Lacroix e t al. 2003	Yes: Long-tailed Duck	No: Beaufort Sea, Alaska	No: underwater seismic surveys	1	1
Miller et al. 1994	Yes: Pacific Black Brant	No: Teshekpuk Lake, Alaska	No: modeling helicopter overflight	1	1
Mikola et al. 1994	No: Velvet Scoter	No: Archipelago of Turku, Finland	No: motorboat	0	1
Pierce et al. 1993	No: Moorhen, Purple Gallinule, Little Grebe, and Yellow Bittern	No: East Coast Peninsular Thailand	No: canoe and motorized canoe	0	1
Reijnen et al. 1995	No: passerines	No: The Netherlands	No: car traffic	0	2
Robinson. and Pollitt 2002	No: waterbirds (unknown species composition)	No: United Kingdom	No: motorboat, rowboat, windsurfer, jet-ski	0	2
Rodgers and Schwikert 2003	Yes: Bald Eagle, Great Blue Heron (+11 species not found or common in GBNP)	No: Central Florida	No: airboats (powerboats with airplane motors)	1	1

Study Year	Common Species	Location	Vessel behavior	Relevance Score*	Rigor Score**
Rodgers. and Schwikert 2002	Yes: Great Blue Heron (23 other species not found or common in GBNP)	No: West and East Coasts of Florida	No: jet-ski and powerboat	1	1
Rodgers and Smith 1997	No: Brown Pelican, Anhinga, Great Egret, Wood Stork	No: North and Central Florida	No: powerboat	0	1
Rodgers. and Smith 1995	Yes: Great Blue Heron (other 9 species not found or common in GBNP)	No: North and Central Florida	No: powerboat	1	1
Ronconi. and St Clair 2002	No: Black Guillemot	No: Bay of Fundy, Canada	No: powerboat, sailboat, mid-size outboard	0	4
Schummer and Eddleman 2003	No: American Coot, American White Pelican, Black Tern, Blue-Winged Teal and Franklin's Gull	No: South-Central Oklahoma	No: fishing boat	0	1
Stolen 2003	No: Snowy Egret, Great Egret, and Tricolored Heron	No: Merritt Island National Wildlife Refuge, Florida	No: car traffic	0	1
Stone 2000	No: passerines	No: Bolder, Colorado	No: urban noise	0	2
Titus and Vandruff 1981	Yes: Common Loon	No: Northeastern Minnesota	No: canoe and motorized canoe	1	3
Traut. and Hostetler 2003	Yes: waterbird guilds- Divers and Ducks (species composition unknown)	No: Winterhaven, Florida	No: motorboat	1	3
Tuite et al. 1984	Yes: mallard (8 other species not found or common in GBNP)	No: Britain (England and Wales)	No: sailboat, row boat, power-boat, water-skiing, windsurfing	1	2
Ward et al. 1999	Yes: Pacific Brant and Canada Geese	No: Southwestern Alaska	No: aircraft overflight	1	4

Study Year	Common Species	Location	Vessel behavior	Relevance Score*	Rigor Score**
Wood 1999	Yes: Bald Eagle	No: Northcentral Florida	No: motorboat, sailboat, canoe	1	3

* Relevance Score is an index of applicability of a study to the question of cruise ship impacts to avian species in GBNP, using a scale of 0 (not applicable) to three (highly applicable).
** Rigor Score is an index of study design rigor, using a scale of 1(very rigorous) to 4(observational), as defined by Hill et al 1997.

Appendix E:

Potential Impacts of Cruise Ships on the Lower Trophic Level Species of Glacier Bay

Potential Impacts of Cruise Ships on the Lower Trophic Level Species of Glacier Bay

Literature Review Prepared for the
Glacier Bay National Park and Preserve
Vessel Management Science Advisory Board

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General considerations

Very little data are available to accurately assess the impacts from cruise ships on lower trophic level species. Most of the available research published on ship disturbance to lower-trophic level species has been carried out to determine: 1) bias in acoustic biomass sampling or 2) impact to catch rates (from vessel presence, vessel-generated noise, or seismic-generated noise). Therefore, assessing the impacts of ship avoidance behavior, especially impacts to reduced survival/fecundity, on lower-trophic level species in Glacier Bay is challenging. Furthermore, the majority of data available are descriptive in nature and changes in behavior are rarely evaluated quantitatively. However, when evaluating the existing research, the following general patterns do emerge:

1) Fish alter/change their behavior in response to ship presence as well as vessel-generated noise.
2) Fish can have a physiological impact (damaged hearing systems) after exposure to anthropogenic noise such as air guns (used for seismic surveys).
3) Invertebrates (krill, decapods, etc.) have the capacity to hear/sense sound and respond behaviorally to this sound/vibration source.

Critical Gaps in Knowledge and Prioritization of Suggested Research

Currently there is limited, if any, data available to understand the impacts of cruise ships to lower-trophic level species. Research prioritizations include:

1) Assessments of lower-trophic level species life history to determine when recruitment occurs and during what time of year eggs/larval fish are vulnerable for disturbance.
2) Measure/characterize the sound generated from cruise ships to compare against published data that assess exposures effect levels (Suzuki et al. 1980, Pearson et al. 1992).
3) Study changes in fish behavior in the presence of cruise ships.

Summary of Impacts by Category

A. General Disturbance (these papers did not distinguish between sound, visual, or physical disturbance)
General impacts associated with ships can be broadly categorized into direct and indirect stressors. Direct effects include fish mortality caused by the physical forces generated from a moving vessel while indirect effects are more subtle behavioral changes which can prevent organisms from allocating resources to food provisioning, care of young, etc.

i) behavioral impacts

Multiple studies have documented changes in fish behavior in the presence of ships. Typically these behavior changes have been described as avoidance reactions and alarm/startle responses. Responses include body tilting as well as horizontal and vertical swimming (Vabo et al. 2002). Vertical diving up to 5 or 10 meters in depth in response to a vessel passing overhead was observed in several studies (Gerlotto and Freon 1992, Gerlotto et al. 2004).

ii) physiological impacts

Besides potential mortality from physical forces generated by ships, no studies evaluated physiological impacts from general ship disturbance to lower trophic level species. However, stress responses in general can cause physiological changes in animals and there is the possibility that a stress response is causing a physiological impact (i.e., release of stress hormones) in lower trophic-level species.

Behavior changes in response to ship disturbance can also potentially impact organisms in subtle ways. Energy used for an avoidance reaction takes away from energy available for food provisioning, care of young, disease resistance, etc.. Gill et al. (1996) discuss how animals are faced with a trade-off between resource use and risk of disturbance and that these trade-offs can be quantified by measuring the amount of resources not used under disturbed conditions.

iii) demographic impacts

Egg and larval stages appear to be most vulnerable to direct impacts from ship disturbance. Physical forces such as wave energy, return currents, and shear stress can cause direct fish mortality as well as dislodgement and redistribution of eggs (Jude et al. 1998, Wolter and Arlinghaus 2003).

B. Sound/Vibrations

The majority of research on the impacts of sound/vibrations on lower trophic-level species assess: i) the impact of sound (vessel-generated as well as air gun surveys) on fish catch rates, ii) the amount of bias fish avoidance behavior has on acoustic surveys, and iii) physiological damage (or stimulation for invertebrates) of hearing systems.

i) behavioral impacts

Behavioral impact studies from sound can be divided into the following categories:

1) Fish: Sound produced from air guns can alter catch rates of cod and haddock (Engas et al. 1996) up to 18 miles from a seismic shooting area. In addition, Pearson et al. (1992) exposed penned rockfish (*Sebastes spp*.) to air gun sounds and found 1) shifts in vertical distribution, 2) shifts in behavior, 3) occurrence of alarm and startle responses.
2) Fish: Vessel-generated noise was also shown to alter fish behavior. A study by Engas et al. (1995) provided some of the most relevant data on changes in behavior from vessel-generated noise. They exposed penned wild cod (*Gadus morhua* L.) and herring (*Clupea harengus* L.) to playback trawl recordings and found that fish exhibited avoidance behavioral responses such as change in schooling behavior, slow diving, and diagonal swimming near the bottom of their pen.
3) Invertebrates, decapods/krill: Ability to hear and respond to underwater sounds/vibrations. A review by Popper et al. (2001) proposes that crustaceans are able to detect and use sound in ways that parallel aquatic and terrestrial vertebrates and that evidence suggests that some crustaceans respond behaviorally to the presence of underwater sound. Wiese and Marschall (1990) present data that show Antarctic krill (*Euphausia suprebra*) have the sensory capacity to respond to water and flow vibration.

ii) physiological impacts

A few studies evaluated the physiological changes as a result of exposure to anthropogenic sound in fish (Hastings et al. 1996, McCauley et al. 2003). Exposure to 300 Hz of low frequency sound was able to cause some, although limited, damage to hair cells in oscars (*Astronotus ocellatus*) (Hastings et al. 1996) while pink snapper (*Pagrus auratus*) exposed to air gun sounds experienced extensive irreversible damage to their hearing system (McCauley et al. 2003).

iii) demographic impacts

Tolimieri et al. (2002) demonstrated that larval reef fish (triplefin, *Tripterygiidae*) use reef-generated ambient sound as a settlement navigational cue. These results suggest cruise ship-generated noise may interfere with the ability of larval fish to navigate using ambient sounds, and thus impact settlement rates.

C. Summary of impacts to higher trophic-level species

The primary impact to higher trophic-level species (such as seals, seabirds, sea otters, etc.) is through a reduction in prey availability in the following manner:

1) A direct impact in prey abundance when prey, such as fish, exhibit ship-avoidance behavior and leave disturbed areas.

2) A reduction in biomass from a decrease in larval/egg survival due to the physical forces generated from cruise ships (Jude et al. 1998, Wolter and Arlinghaus 2003).

3) A reduction in recruitment or change in settlement patterns (Tolimieri et al. 2002).

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Engas, A., O. A. Misund, A. V. Soldal, B. Horvei, and A. Solstad. 1995. Reactions of Penned Herring and Cod to Playback of Original, Frequency-Filtered and Time-Smoothed Vessel Sound. Fisheries Research **22**:243-254.

Gerlotto, F., J. Castillo, A. Saavedra, M. A. Barbieri, M. Espejo, and P. Cotel. 2004. Three-dimensional structure and avoidance behaviour of anchovy and common sardine schools in central southern Chile. Ices Journal of Marine Science **61**:1120-1126.

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McCauley, R. D., J. Fewtrell, and A. N. Popper. 2003. High intensity anthropogenic sound damages fish ears. Journal of the Acoustical Society of America **113**:638-642.

Pearson, W. H., J. R. Skalski, and C. I. Malme. 1992. Effects of Sounds from a Geophysical Survey Device on Behavior of Captive Rockfish (*Sebastes Spp*). Canadian Journal of Fisheries and Aquatic Sciences **49**:1343-1356.

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Breithaupt, T., and J. Tautz. 1990. The sensitivity of crayfish mechanoreceptors to hydrodynamic and acoustic stimuli. Pages 114 -120 *in* K. Wiese, W.-D. Krenz, J. Tautz, H. Reichert, and B. Mulloney, editors. Frontiers in Crustacean Neurobiology. Birkhauser Verlag, Basel.

Sound/Vibrations. This book chapter by Breithaupt and Tautz describes different types of crayfish hydrodynamic and acoustic receptors. The authors state that although behavioral tests of American lobster confirm that these animals cannot "hear" per say (i.e., respond to the pressure component of sound), they react to particle velocity close to a sound source. The threshold curves of hydrodynamic receptors of decapod crustacea are reported to be below 150 Hz and, in addition to frequency, the spatial dimension of hydrodynamic events is important to stimulate crustacean receptor systems. Although there appears to be little evidence for negative impacts from vessel-generated noise/vibrations to crustaceans, the ability of crustacean sensory systems to be stimulated by particle velocity allows for the possibility of altered behavior in response to ship disturbance. **Rigor Score = R**

Engas, A., and S. Lokkeborg. 2002. Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates. Bioacoustics **12**:313-316.

Sound/Vibrations. The authors review evidence for the decline of catch rates during seismic surveys. They state that the frequency spectra of air guns and vessel-generated noise fall within the auditory range of fish. In addition, they present evidence that behavioral response patterns of fish change in response to ship (e.g., propeller) and air gun generated noise. They conclude that, despite previous efforts, few experiments have been conducted to determine effects of vessel noise on catch rates. Even though the authors bring up some interesting points, this review is brief and does not appear to be a comprehensive assessment of the available literature. **Rigor Score = R**

Engas, A., S. Lokkeborg, E. Ona, and A. V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Sciences **53**:2238-2249.

Sound/Vibrations. The authors describe the impacts of noise generated from air guns (seismic shooting) on the abundance and catch rates of cod and haddock. Acoustic mapping and fishing trials were conducted in the central Barents Sea 7 days before, during, and 5 days after a seismic shooting event. A reduction in catch rates were observed 18 nautical miles from the seismic shooting area, with the most prominent reduction occurring within the shooting area where haddock and cod trawl catch rates were reduced by ~70 % and longline catch rates were reduced by ~70% for haddock and 45% for cod. In addition, the abundance and catch rates did not return to pre-shooting levels during the 5-day period after the shooting event. Because the authors evaluated the impacts of noise generated from air guns their results are not directly applicable to noise generated from cruiseships. However, due to the lack of information that

exists on the effects of noise generated from ships on lower vertebrate species, this study helps to provide evidence that anthropogenic sound can alter fish behavior. **Rigor Score = 4**

Engas, A., O. A. Misund, A. V. Soldal, B. Horvei, and A. Solstad. 1995. Reactions of Penned Herring and Cod to Playback of Original, Frequency-Filtered and Time-Smoothed Vessel Sound. Fisheries Research **22**:243-254.

Sound/Vibrations. The authors describe an experimental study in which the behavioral responses of penned cod (*Gadus morhua* L.) and herring (*Clupea harengus* L.) were tested in response to playback trawl recordings. Wild cod and herring were captured and placed in pens located in a sheltered coastal area outside of Bergen, Norway, during the spring of 1989. An underwater loudspeaker was positioned outside the pen (2 m depth and a distance of 11 m from the nearest net wall). Behavioral responses were recorded with an underwater TV camera and categorized as i) no response, ii) avoidance response, and iii) alarm response. Results showed the fish only exhibited avoidance behavioral responses (e.g., change in schooling behavior, slow diving, diagonal swimming near bottom of pen), no alarm responses were observed. Furthermore, the authors found a substantial variation in response behavior between the experimental trials for both cod and herring with external stimuli (strong tide-currents, sunlight, presence of potential predators outside pen) weakening the strength of the response. These results demonstrate that both cod and herring do exhibit altered behavior in response to ship-generated noise, but this behavior appears to be highly variable. **Rigor Score = 4**

Fernandes, P. G., A. S. Brierley, E. J. Simmonds, N. W. Millard, S. D. McPhail, F. Armstrong, P. Stevenson, and M. Squiress. 2000. Oceanography - Fish do not avoid survey vessels. Nature **404**:35-36.

General. Fernandes et al. used an autonomous underwater vehicle (AUV) to detect if fish avoided acoustic survey vessels. The authors found that herring (*Clupea harengus*) abundance calculated by the AUV and research vessel were significantly correlated ($r = 0.935$, $P < 0.001$) with each other, demonstrating that vessel avoidance is not a significant source of bias for acoustic abundance estimates. As these results did not evaluate changes in school structure due to vessel presence, this study has limited applicability for understanding ship-induced behavioral changes in fish. In addition, these data provide no insight into how avoidance behavior could result in reduced fish survival or fecundity in Glacier Bay. **Rigor Score = 4**

Freon, P., F. Gerlotto, and M. Soria. 1992. Changes in School Structure According to External Stimuli - Description and Influence on Acoustic Assessment. Fisheries Research **15**:45-66.

General. The purpose of this study was to evaluate the impact of school structure on acoustic assessment; however, because of the methods employed, data were generated on vessel-induced fish disturbance. Several visual observations and acoustic measurements were conducted with and without disturbance (e.g., research vessel, airplane shadow) to measure the change in schooling fish structure. A vessel passing overhead created measurable changes in the schooling structure of tropical sardines. These school structure changes were based on observations and purely descriptive in nature. The authors did not statistically evaluate the change in schooling structure, as the main goal of the paper was acoustic detection of fish biomass. **Rigor Score = 3**

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology **6**:11.

General. Frid and Dill present an emerging paradigm that predation and non-lethal disturbance create similar trade-offs to the individual. These tradeoffs are between avoiding the perceived predation risk and fitness-enhancing activities such as feeding, parental care, or mating. Studies examining antipredator behavior are discussed with respect to trade-offs related to energy use, mating, parental investment, and indirect effects on populations and communities. The

authors argue why, from an evolutionary perspective, disturbance stimuli should be considered analogous to predation risk and the importance of using a risk-disturbance hypothesis framework in disturbance studies. Because of the absence of data that quantifies ship disturbance to lower vertebrate species on survival and/or fecundity, the risk-disturbance hypothesis approach may help translate avoidance behavior into some measure of either short-tem or long-term cost to the organism. **Rigor Score = R**

Gerlotto, F., J. Castillo, A. Saavedra, M. A. Barbieri, M. Espejo, and P. Cotel. 2004. Three-dimensional structure and avoidance behaviour of anchovy and common sardine schools in central southern Chile. Ices Journal of Marine Science **61**:1120-1126.

General. Acoustic data collected from a ship survey in the central zone off Chile in January 2002 were used to assess the vertical and horizontal ship avoidance behavior of anchovy and sardine schools. Limited vertical avoidance as seen by fish diving from the surface to 5-10 m depths below the vessel was observed. No horizontal avoidance behavior was observed. The authors conclude that despite the limited vertical diving, sardine and anchovy do not avoid survey vessels, but caution that no general fish avoidance behavior should be assumed from their results. The authors describe previous studies that show schooling fish have highly variable ship avoidance patterns. These data document schooling fish demonstrate a change in behavior due to ship presence, however, the applicability of this observed limited stress response to cruiseship use in Glacier Bay is unclear. **Rigor Score = 1**

Gerlotto, F., and P. Freon. 1992. Some Elements on Vertical Avoidance of Fish Schools to a Vessel During Acoustic Surveys. Fisheries Research **14**:251-259.

General. The authors present observational results from a study off Venezuela of five fish schools (*Sardinella aurita*) that were observed successively from a drifting dingy and by a research vessel immediately after it passed over the schools. One goal of this study was to estimate the bias involved with vertical avoidance behavior during acoustic surveys. The authors found 1) all five fish schools dived vertically before the overhead passage of the vessel and the mean dive depth was 5 m, 2) the school nearest to the surface dived the deepest, 3) the five schools compressed as well as vertically migrated, and 4) the intensity of the avoidance behavior was dependent upon the distance of the stimulus. These observations provide evidence that *S. aurita* exhibit behavior changes when vessels pass overhead. However, this study does not address the negative consequences of vertical avoidance behavior to reproduction and/or survival. **Rigor Score = 1**

Gill, J. A., K. Norris, and W. J. Sutherland. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation **97**:265-268.

General. Gill and coauthors present some fundamental concepts of how behavioral responses are used to quantify human disturbance and thus predict potential impacts to populations. They discuss that avoidance of disturbance need not reflect population-level consequences and species which are unable to move to an alternative habitat could be at greater risk for decreased fitness. The arguments presented in this article may be important when determining which species are at risk to disturbance from cruiseships in Glacier Bay. Some species, crustaceans for example, may be restricted in their habitat and unable to move to avoid ship disturbance. Literature discussed in this review documents that crustaceans are sensitive to vibrations, and thus potentially negatively affected from cruiseships. **Rigor Score = R**

Gill, J. A., W. J. Sutherland, and A. R. Watkinson. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology **33**:786-792.

General. Gill and coauthors discuss the inherent difficulties with measuring the extent and consequences of human disturbance on wildlife. They present results from a disturbance

study on pink-footed geese, *Anser brachyrhynchus*. Although the authors' findings are not directly applicable to cruiseship impacts on lower trophic level species, their method of evaluating human disturbance may prove relevant. Gill and coauthors argue that human disturbance mainly acts in subtle ways, and impacts to wildlife populations are difficult to assess. Their study describes how animals are faced with a trade-off between resource use and risk of disturbance and that these trade-offs can be quantified by measuring the amount of resources not used under disturbed conditions. **Rigor Score = 3**

Hastings, M. C., A. N. Popper, J. J. Finneran, and P. J. Lanford. 1996. Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatu*s. Journal of the Acoustical Society of America **99**:1759-1766.

Sound/Vibrations. The goal of this study was to examine the effects of low-frequency sound on the hearing structure of fish. An experimental design was used in which fish (*Astronotus ocellatus,* the oscar) were exposed to different levels of low frequency sounds and allowed to survive for one or four days post exposure. The authors found that only the highest level of tones (300 Hz) caused some, but limited, hair cell damage in the ears of the oscar. Furthermore, hair cell damage was only observed in individuals that were allowed to survive for four days post exposure, suggesting this damage may develop slowly. **Rigor Score = 4**

Jude, D. J., F. G. Tesar, and H. T. Tin. 1998. Spring distribution and abundance of larval fishes in the St. Marys River, with a note on potential effects of freighter traffic on survival of eggs and larvae. Journal of Great Lakes Research **24**:569-581.

General. The authors describe results from a larval fish survey in the St. Marys River from late April to late May in order to evaluate the potential effects of increasing freighter ship traffic on fish egg and larval survival. Data for larval fish densities and depths were collected along seven transects. The authors state that fish larvae and eggs are vulnerable to ship traffic disturbance, such as increased re-suspension of sediments, dislodgment of eggs, and premature emergence of larvae. Although the authors present egg and larval survey data in a river system, the lack of information available on ship impacts to lower vertebrate species makes this study relevant for determining ways to assess effects from increased ship traffic in Glacier Bay. **Rigor Score = 1**

McCauley, R. D., J. Fewtrell, and A. N. Popper. 2003. High intensity anthropogenic sound damages fish ears. Journal of the Acoustical Society of America **113**:638-642.

Sound/Vibrations. The purpose of this study was to investigate the possible physiological impacts from high-energy noise sources on the hearing systems of fish. High energy noise can be produced from air guns, and occur as short, sharp, low frequency sound. An experimental approach was used in which the authors carried out trials with pink snapper (*Pagrus auratus*) held in cages. An air gun, designed to mimic the sound of a passing seismic vessel, was towed away from the cages. The results showed that fish exposed to an operating air gun had extensive damage to their hearing system as reflected by ablated hair cells in their sensory epithelia. Furthermore, this damage appeared irreversible, with no evidence of repair or replacement up to 58 days after exposure. Although cruiseships are not known to emit the similar sharp, low frequency sound such as that produced from an air gun in this study, these results demonstrate that fish hearing systems are capable of being damaged from exposure to high intensity sound. **Rigor Score = 4**

Pearson, W. H., J. R. Skalski, and C. I. Malme. 1992. Effects of Sounds from a Geophysical Survey Device on Behavior of Captive Rockfish (*Sebastes Spp*). Canadian Journal of Fisheries and Aquatic Sciences **49**:1343-1356.

Sound/Vibrations. Pearson et al. describe an experimental study in which they examined the behavioral responses of penned (held in field enclosures) rockfish (*Sebastes spp.)* after exposure to air gun sounds. The authors conclude that air gun noises did result in behavioral changes in penned rockfish and that the general threshold for the alarm response was about 180 dB re 1 µPa. Observed behavior changes in rockfish included 1) shifts in vertical distribution, 2) shifts in behavior, 3) occurrence of alarm and startle responses. This study, which was conducted to establish parameters for a subsequent evaluation of geophysical surveys on fishing success, is not directly applicable to vessel-generated noise. However, the results from this work provide evidence that several rockfish species react to sound with alarm and startle responses, even though this response appeared transitory and the long-term impact of this response on fish survival is unknown. **Rigor Score = 4**

Popper, A. N. 2003. Effects of anthropogenic sounds on fishes. Fisheries **28**:24-31.

Sound/Vibrations. Popper reviews how anthropogenic sound may affect fish behavior and physiology. Most anthropogenic sounds are of lower frequency (under 1,000 Hz), and Popper provides data that demonstrate fish are able to detect sounds in these low frequency ranges. The importance of sound to fish behavior and physiology is discussed. Even though limited data are available, data suggest short or long-term exposure to loud sounds may alter fish behavior and result in temporary or permanent loss of hearing. **Rigor Score = R**

Popper, A. N., M. Salmon, and K. W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology **187**:83-89.

Sound/Vibrations. The authors review behavioral, physiological, anatomical, and ecological aspects of sound and vibration detection in decapod crustaceans with the intent to demonstrate that despite the limited available data, evidence suggests these crustaceans are able to detect and use sound in ways that parallel aquatic and terrestrial vertebrates. Of particular interest to this review, the authors discuss evidence that some crustaceans respond behaviorally to the presence of underwater sound, and that most, if not all, decapods have sensory structures capable of responding to vibrational stimuli. The evidence that decapods can and do modify their behavior in response to sound/vibrations opens up the possibility that cruiseships are able to impact decapod behavior in Glacier Bay. **Rigor Score = R**

Soria, M., P. Freon, and F. Gerlotto. 1996. Analysis of vessel influence on spatial behaviour of fish schools using a multi-beam sonar and consequences for biomass estimates by echo-sounder. Ices Journal of Marine Science **53**:453-458.

Sound/Vibrations. The goal of this study was to analyze vessel influence on the spatial behavior of fish schools to determine vessel avoidance bias on acoustic measurements of fish biomass. Data were collected from two acoustic surveys carried out in the Mediterranean. The primary fish schools surveyed were anchovies and sardines. The authors demonstrate that fish do exhibit both lateral and vertical avoidance behavior in response to ships passing overhead. The magnitude of this behavior was directly related to the magnitude of the stimulus (i.e. the proximity to the research vessel). The applicability of this research to cruiseship use in Glacier Bay is not clear, as these results do not provide any information on the short or long-term impact of ship avoidance behavior on fish survivorship and/or fecundity. **Rigor Score = 1**

Suzuki, H., E. Hamada, K. Saito, Y. Maniwa, and Y. Shirai. 1980. The Influence of Underwater Sound on Marine Organisms. Journal of Navigation **33**:291-295.

Sound/Vibrations. The authors conduct a series of measurements and experiments to better understand the influence of underwater sound on fish species. Measurements of levels of underwater sound produced by different sizes/types of ships are reported, such as the underwater

sound of a 990-ton vessel reaches 127 dB at a distance of 200 m, which might be of use when predicting the level of underwater sound generated from cruiseships in Glacier Bay. In addition, the authors carried out a series of experiments in an aquarium in order to evaluate the impact of underwater sound of fish behavior. A table is presented of the sound threshold for various fish species (n = 11), such as anchovy, yellowtail, and grouper. The authors conclude that a sound level of 130 to 150 dB can frighten fish and make them dive vertically several meters. 130 to 150 dB can be experienced within 400 m of a large tanker or within 50 m of a small purse-seiner. **Rigor Score = 4**

Tolimieri, N., O. Haine, J. C. Montgomery, and A. Jeffs. 2002. Ambient sound as a navigational cue for larval reef fish. Bioacoustics **12**:214-217.

Sound/Vibrations. The goal of this study was to evaluate the importance of sound for larval fish dispersal and settlement. Specifically, the authors were interested in determining if larval reef fish use biological sound to guide their movements towards the reef. Light traps were deployed in pairs ~500 m apart where one trap had a loudspeaker positioned ~3 m away replaying recorded reef sound. The results showed that the "sound" traps had a significantly ($P < 0.05$) higher percentage of larvae from triplefin (*Tripterygiidae*) reef fish compared to the "silent" traps. The authors conclude that ambient sound may provide an important navigational cue for pre-settlement fish. Therefore, sounds generated from anthropogenic activities, such as cruiseships, may have the potential to interfere with the ability of larval fish to navigate using ambient sounds. **Rigor Score = 4**

Vabo, R., K. Olsen, and I. Huse. 2002. The effect of vessel avoidance of wintering Norwegian spring spawning herring. Fisheries Research **58**:59-77.

General. The authors used an experimental approach to measure the relative variation in echo energy values (generated from a submerged 38 kHz transducer) of fish schools during the passage of a survey vessel. Experiments were carried out during nighttime and daytime settings and a quantification of the loss of echo energy due to vessel avoidance was presented. The authors classified all systematic changes in acoustic densities around the time of the vessel passing as avoidance reactions and determined that body tilting as well as vertical and horizontal swimming were important behavioral reactions. The authors also concluded that depth was a major predictor for the severity of avoidance reactions, with most reactions fading out below 100m. No significant avoidance reactions were observed below depths of 150 m. This study provides results from 42 experiments as well as a rigorous quantification of avoidance patterns in schooling fish (e.g., herring). These data can be used to demonstrate that fish do exhibit quantifiable avoidance patterns from passing vessels. **Rigor Score = 4**

Wiese, K., and H. P. Marschall. 1990. Sensitivity to vibration and turbulence of water in context with schooling in Antarctic krill *Euphausia suprebra*. Pages 121- 130 *in* K. Wiese, W.-D. Krenz, J. Tautz, H. Reichert, and B. Mulloney, editors. Frontiers in Crustacean Neurobiology. Birkhauser Verlag, Basel.

Sound/Vibrations. Wiese and Marschall describe an experiment in which they report the sensory capacity of Antarctic krill (*Euphausia suprebra*) with respect to water and flow vibration. The authors discuss the potential role of sensory cell activity for intra-specific communication during krill schooling. Due to the lack of studies examining sensory systems in invertebrate species, this study is important in that it demonstrates a potential mechanism with which krill behavior can be impacted by vibrational disturbance. **Rigor Score = 1**

Wolter, C., and R. Arlinghaus. 2003. Navigation impacts on freshwater fish assemblages: the ecological relevance of swimming performance. Reviews in Fish Biology and Fisheries **13**:63-89.

General. Wolter and Arlinghaus investigate navigational impacts in order to improve the evaluation of navigational effects on fish assemblages. They use a model-based approach to examine available studies on swimming performances of fish, such as length-specific burst and critical swimming speeds. Absolute speed was concluded to be the best predictor for fish thresholds and habitat use limitations from hydraulic forces. The authors' theoretical findings were that under common waterway navigational conditions (return currents along shore = 0.8 m s^{-1} with a 0.1-0.3 m drawdown) the threshold for small fish survival was estimated at 147 mm total length at critical swimming performance (>20 s-60 min without fatigue) and 47 mm at burst performance (> 20 s). These findings were also supported by empirical studies of fish recruitment in waterways. The authors conclude that many direct and indirect impacts on fish could result from physical forces associated with shipping. Furthermore, the strong dependence of fish recruitment on these hydraulic forces opens up the possibilities of formulating suitable criteria for safe ship operation (speed and distance from bank). Although this study was aimed at determining the impacts of shipping in waterways (primarily freshwater), the authors raise some important points regarding shipping impacts to fish recruitment which may be applicable to cruiseship use in Glacier Bay. **Rigor Score = 2**

Relevancy Table for Annotated References – Lower Trophic Levels

Study	Research type	Common Species	Location	Vessel Behavior	Vessel Type	Rigor Score*
General						
Fernandes et al. 2000	Field-based	Yes: herring	No: North Sea	No: survey	No: research	4
Freon et al. 1992	Field-based	Yes: sardines	No: Venezuela	No: survey	No: research	3
Frid and Dill 2002	Review	NA	NA	NA	NA	R
Gerlotto et al. 2004	Field-based	Yes: sardines	No: Chile	No: survey	No: research	1
Gerlotto and Freon 1992	Field-based	Yes: sardines	No: Venezuela	No: survey	No: research	1
Gill et al. 2001	Review	NA	NA	NA	NA	R
Gill et al. 1996	Review	NA	NA	NA	NA	3
Jude et al. 1998	Field-based	No: lake whitefish/herring	No: St. Mary's River	No: river transect	No: freighters	1
Vabo et al. 2002	Field-based	Yes: herring	No: Norway	No: survey	No: research	4
Wolter and Arlinghaus 2003	Field/model based	No: sturgeons, catfish	No: river systems	NA	NA	2
Sound/Vibrations						
Breithaupt and Tautz 1990	Review	Yes: crustaceans	NA	NA	NA	R
Engas et al. 1995	Field-based	Yes: cod	No: Norway	No: fishing	No: trawl	4
Engas et al. 1996	Field-based	Yes: cod	No: Barents Sea	No: air gun	No: seismic	4
Engas and Lokkeborg 2002	Review	Yes: rockfish	NA	No: fishing	No: trawlers, longline	R
Hastings et al. 1996	Lab-based	No: oscar	NA	NA	NA	4
McCauley et al. 2003	Field-based	No: pink snapper	No: Australia	No: air gun	No: seismic	4
Pearson et al. 1992	Field-based	Yes: rockfish	No: California	No: air gun	No: seismic	4

Study	Research type	Common Species	Location	Vessel Behavior	Vessel Type	Rigor Score*
Popper 2003	Review	Yes: cod	NA	NA	NA	R
Popper et al. 2001	Review	Yes: crustaceans	NA	NA	NA	R
Soria et al. 1996	Field-based	Yes: sardines	No: Mediterranean	No: survey	No: research	1
Suzuki et al. 1980	Lab/field-based	Yes: flounder	No: Tokyo Bay	Yes: general movement	Yes: passenger/cruise	4
Tolimieri et al. 2002	Field-based	No: triplefin	No: New Zealand	NA	NA	4
Wiese and Marschall 1990	Lab-based	No: Antarctic krill	NA	NA	NA	1

* Rigor Score is an index of study design rigor, using a scale of 1(very rigorous) to 4(observational), as defined by Hill et al 1997.

Appendix F:

Visitor Experience in Glacier Bay National Park & Preserve: A Literature Review

Visitor Experience in Glacier Bay National Park and Preserve

A Literature Review Prepared for the
Glacier Bay National Park and Preserve
Vessel Management Science Advisory Board

Prepared by:
Debra L. Clausen
Sundberg & Clausen

INTRODUCTION

Glacier Bay was set aside as a National Monument in 1925. In 1980 Glacier Bay National Park & Preserve was established to "*preserve its accessible tidewater glaciers, superlative scenic grandeur, historic value, unique opportunities for the study of glaciers and associated plant and animal community succession processes, fish and wildlife populations and their habitats, unaltered and undisturbed ecosystems and opportunities for scientific research, and wilderness resources values and related recreational opportunities."*

Over 75% of Glacier Bay National Park & Preserve's approximately 3.3 million acres are designated as part of the National Wilderness Preservation System (USDOI-NPS, 2003), including most of the land in the park and five marine wilderness waterways: the Beardslee Islands, Upper Dundas Bay, the Hugh Miller/Scidmore Complex, Adams Inlet, and Rendu Inlet. Glacier Bay Wilderness preserves intact temperate rainforest and productive marine ecosystems as well as dynamic tidewater glaciers. It is the unique opportunity to view and experience this rare combination of natural treasures that draws approximately 400,000 visitors annually. Approximately ninety-five percent of park visitors are cruise ship passengers (Nemeth-NPS, 2005). Tour vessel passengers, charter vessel passengers, private vessel visitors and backcountry visitors comprise the remaining five percent.

The National Park Service is tasked with managing Wilderness System lands and waters to preserve natural conditions. Wilderness is defined by the Wilderness Act as an area which, *"(1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."*

Pressure to increase cruise ship vessel traffic in Glacier Bay has raised the management question, "How will an increase in the number of cruise ships

visiting Glacier Bay National Park & Preserve affect the experience of other visitors?" Given the park mission established by enabling legislation, what are the acceptable limits of cruise ship density in Glacier Bay?

The goal of this literature review is to provide an objective analysis of existing research on the potential effects of cruise ship tourism on the visitor experience within national parks and protected areas. This literature review was conducted in support of the social science team of the Glacier Bay Science Advisory Board, which was formed to develop a research framework to understand the possible implications of increased cruise ship traffic to Glacier Bay National Park & Preserve. The social science team considered three areas: visitor effects, socioeconomic effects, and cultural implications. This review organized and summarized existing literature that dealt with the first area only. The intent of this review is to identify relevant findings from a broad set of studies of visitor experiences and impacts that would apply to the question of cruise ship visitation to Glacier Bay and that would assist Board members in the development of a research framework.

This report is intended to be a resource and an aid in framing questions, designing research, developing monitoring protocols; and choosing a management framework in which to address the issue of visitor experience in Glacier Bay National Park & Preserve.

This report outlines the scope and complexity of visitor experience and its management. It presents a literature review of pertinent references. Major themes in the literature and their application to Glacier Bay National Park & Preserve visitor experience management issues are discussed. A consideration of the applicability and rigor in the existing body of literature is provided. Finally, the report identifies critical gaps in knowledge, suggests possible directions for future research, and offers concluding thoughts.

METHODOLOGY

Initially, expert sources were contacted to help identify pertinent literature and relevant studies. Experts in the fields of park and wilderness management, recreation research, and local Glacier Bay knowledge provided assistance in identifying what is known about visitor experience in Glacier Bay. They also directed attention to applicable studies from other national parks and natural areas. Discussions with the experts were helpful in refining the focus of this report, in formulating appropriate questions, and in identifying and describing gaps in knowledge. Experts contacted include:

- Darryll Johnson, National Biological Survey, Cooperative Park Studies Unit, University of Washington
- Mark Vande Camp, National Biological Survey, Cooperative Park Studies Unit, University of Washington

- Margaret Littlejohn, VSP Coordinator, National Park Service, Cooperative Park Studies Unit, University of Idaho
- Katie Kneeshaw, Aldo Leopold Wilderness Research Institute, USDA Forest Service Missoula, Montana
- Brian Glaspell, U.S. Fish and Wildlife Service, Anchorage, Alaska
- David Nemeth, Glacier Bay National Park & Preserve
- Greg Streveler, Local Expert, Gustavus, Alaska
- Paul Lachapelle, National Human Use Management Specialist, Parks Canada
- Frances Gertsch, National Human Use Management Specialist, Parks Canada

A comprehensive literature search was undertaken to locate material on 1) the nature of the visitor experience in natural areas, 2) the scientific measurement of visitor experience in national parks and other recreational outdoor settings, and 3) available planning and management frameworks for addressing visitor experience in parks. Eighty-nine references were reviewed and annotated. Special attention was given to visitor experience issues specific to wilderness areas. Extra effort was made to locate all relevant sources of information on visitor experience in Glacier Bay and to find work addressing the impacts of cruise ships on visitor experience in natural areas. An iterative search process was employed using keywords, literature cited lists from key references, professional journal indices, agency technical report series, and conference and workshop proceedings. All reviewed references were annotated in EndNote. Annotations include keywords provided in the referenced documents. Annotated references were rated according to their applicability to the issue of visitor experience in Glacier Bay National Park & Preserve. Table 1 identifies the relative applicability of reviewed visitor experience literature for Glacier Bay.

Table 1. Applicability of Visitor Experience Literature to Glacier Bay

Category	Applicability	Number of Studies
Visitor Experience	High	7
	Moderate	4
	Low	2
Measuring/Monitoring	High	31
	Moderate	6
	Low	3
Park Planning/Mngmnt	High	15
	Moderate	12
	Low	9

DISCUSSION OF LITERATURE REVIEWED

To address the issue of visitor experience in Glacier Bay it is necessary to first examine what is known about the Glacier Bay National Park & Preserve visitor experience and the management framework that regulates it.

Management documents for Glacier Bay National Park & Preserve (USDOI-NPS 1989, 2000, 2003) outline enabling legislation, other pertinent laws, and applicable regulations. They provide background information on park history, natural resources, uses and activities, and impacts (environmental, social, and managerial). The issue of vessel traffic restrictions is addressed at length in the 2003 Environmental Impact Statement (USDOI-NPS 2003). Visitor experience is addressed in Chapter 3.4.2 and 4.4.2 and an extensive bibliography is provided including references addressing the issue of visitor experience in parks and other outdoor settings. In addition to cruise ship passengers, the EIS identifies four categories of park visitors: backcountry, private vessel, charter vessel, day and overnight tour boats.

Visitor use data has been collected by Glacier Bay Resource Management Division and by National Park Service Cooperative Park Studies Units at the Universities of Washington and Idaho (Salvi et al., 1985; Johnson, 1990, Littlejohn, 2000; Kravolec, 2003; Nemeth, 2005). Several of the park use surveys also solicited respondents' comments. Among the comments were visitor opinions on cruise ship encounters.

Tour boat passengers have been surveyed regarding the effect watercraft and aircraft have had on their enjoyment (Manning et al, 1996; Johnson, 1990). Although the purpose of this survey was to establish norm congruence among tour boat passengers in Glacier Bay National Park, and questions focused on hypothetical encounters, it does reveal tour boat passenger rate increased sightings of cruise ships as increasingly unpleasant.

Park planners and managers charged with providing visitors recreational opportunities in parks and wilderness areas develop management plans and regulations using the best available planning processes and frameworks. First, however, they must seek to understand the nature of the visitor experience being managed and need to review existing visitor use data as well as relevant scientific studies of similar recreational activities in analogous parks and other natural areas.

The literature reviewed in this report can be aggregated into three subject categories: 1) the nature of the visitor experience in natural areas (Visitor Experience 2) the science of measuring and monitoring visitor experience in national parks and other recreational outdoor settings (Measuring and Monitoring), and 3) available planning frameworks for managing visitor experience in national parks (Park Planning and Management). There is overlap

and feedback among these aspects of the visitor experience issue and a final synthesis of these three bodies of knowledge is necessary to the understanding and good management of visitor experience. What follows is a description of each of these subject categories; a discussion of the literature reviewed; consideration of areas of agreement, contradiction and gaps in knowledge; and application of the findings to Glacier Bay National Park & Preserve.

Visitor Experience

There is a rich body of literature narrating personal experience in nature in general and in wilderness specifically. It is important to consult this resource when seeking to understand the value and meaning of the park visitor experience.

John Muir provides one of the earliest written descriptions of Glacier Bay and its magnificent geography (Muir, 1915). Of this experience near Geikie Glacier he says, *"I…set out on an excursion, and spent the day alone on the mountain-slopes above the camp, and northward, to see what I might learn….This was my first general view of Glacier Bay, a solitude of ice and snow and newborn rocks, dim, dreary, mysterious."* That experience and that view are what the Glacier Bay National Park & Preserve is intended to preserve for current and future park visitors.

"Wilderness was the basic ingredient of American civilization. From the raw materials of the physical wilderness Americans built a civilization; with the idea or symbol of wilderness they sought to give that civilization identity and meaning…. Today wild country enjoys widespread popularity: indeed the success of wilderness preservation is now threatened as much from a plethora of enthusiastic visitors as from economic development." (Nash, 1967)

The Wilderness Preservation System was established in 1964 to ensure its protection and preservation. The Wilderness Act describes five principal attributes of wilderness 1) natural conditions 2) opportunities for solitude 3) primitive 4) unconfined type of recreation and 5) remote setting. Over the past forty years wilderness management issues, including the visitor experience in wilderness, have been examined in a well developed field of study (Cole, 1994, 2000; Fox, 2000; Freimund, 2001; Glaspell, 2001, 2003; Hammitt 1982, 1984, 1991, 1995; Higham, 1998; Hollenhorst, 1994; Lawson, 2002; Mace, 2004; Martin, 1989; McCool, 2000; Merigliano, 1990; Nash, 1964; Roggenbuck, 1993; Shelby, 1992; Stankey, 1979, 1985; Washburne, 1982).

Research indicates that the nature of the visitor experience in Glacier Bay National Park and Preserve is affected by three parameters. 1) biophysical conditions 2) social conditions and 3) park management conditions (Cole, 2004). Activities and conditions which impact these three parameters will affect visitor experience in Glacier Bay.

Biophysical Conditions - Potential cruise ship impacts to biophysical conditions include air and visual pollution from engine exhaust, water pollution from intentional or accidental discharges; and disturbance to wildlife viewing from displacement or injury to wildlife (USDOI-NPS, 2003). The quality of the environment affects a visitor's experience in Glacier Bay National Park & Preserve. Studies of noise and visual pollution have addressed these impacts (Harrison, 1980; Mace, 2004). A chronicle of cruise ship troubles in Glacier Bay (Klein, 2002) reveals water pollution violations and a humpback whale collision. No studies have been discovered which address the impact of cruise ship engine and public address system noise on backcountry visitors to Glacier Bay or other wilderness areas.

Social Conditions – Potential cruise ship impacts to social conditions include issues of congruity and appropriateness; effects of crowding and competition; and impaired visitor safety and navigation. The attributes which define a wilderness experience provide the frame outside of which visitor experiences may not meet expectations. When non-cruise ship park visitors (backcountry, private vessel, charter boat, and tour boat visitors) in Glacier Bay arrive expecting solitude, primitiveness, remoteness, privacy and challenge of access and then encounter one or more cruise ships, their actual visitor experience may be significantly at odds with the experience they are seeking.

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A body of literature has explored the importance of solitude and privacy in the wilderness experience. Several of the most pertinent references are reviewed in this report (including Cole, 1997; Cole, 2004; Hammitt, 1984; Hammitt, 1992; Hammitt, 1995; Hollenhorst, 1994). Wilderness solitude has been defined as, "*a form of privacy in a specific environmental setting where individuals experience an acceptable degree of control and choice over the type and amount of information they must process.*" (Hammitt, 1992) "*Emotional release*" and "*resting the mind from anxiety and mental fatigue"* have been shown to best describe the value of privacy in wilderness environment.

The meaning and values visitors attribute to a wilderness experience have also been shown to be important. In the scientific exploration of outdoor recreation, value, significance, and meaning are revealed in social and psychological studies. "*It is not just physical quantities of air pollution and noise that have impact. Factors such as predictability, control, and attributions influence the impact, yet these factors are not addressed in policy. Environmental psychologists have greatly increased our understanding of ambient stressors in urban environments. These same stressors are now prominent in natural areas that were once pristine. Preservation of these areas requires attenuation of the stressors – and not just in physical quantity – for the sake of the environment itself and for the quality of the visitor experience." (Mace, 2004.)*

While the values, meaning and significance of wilderness experience have been examined, the congruity and impact of the presence of one or more cruise ships in that wilderness experience has not been examined. The congruity, appropriateness, and significance of a cruise ship in a remote, primitive area with undeveloped access needs to be researched.

Social issues of density and displacement have a much better researched place in the science of visitor management. However, most of these studies focus on the interaction of individuals or parties of individuals in outdoor recreation settings. The nature and effect of these interactions may be qualitatively different than the nature and effect of cruise ship interactions with other park visitors and therefore may have only partial applicability to Glacier Bay. The many aspects of coping behavior and crowding have been well researched and will be discussed in detail in the section on Measuring and Monitoring the visitor experience.

Visitor safety and safety of navigation for independent park visitors in small boats in the presence of cruise ships has not been examined. The Glacier Bay visitor experience for these recreationists can be significantly affected by the necessity of keeping a safe distance from cruise ships even when navigational rules of the road give the smaller vessel the right-of-way.

Park Management Conditions - Managers of designated wilderness lands and waters within the park are directed to provide a visitor experience which is natural, primitive, remote, unconfined and provides opportunities for solitude (Shafer and Hammitt, 1995). These attributes which characterize a wilderness experience are considered to also encompass opportunities for privacy; spiritual exploration; freedom of choice; self-reliance; challenge of access; and wildlife encounters (Glaspell, et al 2003, Kneeshaw et al 2004). Each of these wilderness experience attributes and opportunities can be impacted by encounters with cruise ships.

Therefore, park management conditions, including the number and scheduling of cruise ships allowed in Glacier Bay, can have a direct impact on the quality of the other visitors' experience. Visitor surveys in Glacier Bay (Salvi and Johnson, 1985; Johnson,1990; Littlejohn, 2000) have investigated visitor attitudes toward the presence of cruise ships, including a section on expectations, preferences and the effect of craft sightings on trip enjoyment. Additional visitor comments about the sighting of cruise ships are also included. There is an absence of data in the literature on the effect of cruise ships on wilderness experience in other locales.

General agreement can be found in the literature regarding the list of important attributes which characterize visitor experience in a national park or wilderness area. There is less understanding of how impacts to the biophysical, social and park management environments can impact the visitor experience.

Measuring and Monitoring

"*Wilderness means different things to different people. Virtually everyone would agree, however, that to be wilderness (in the context of public lands) a place must be relatively uncrowded. To use the particular words contained in the Wilderness Act, wilderness should provide "outstanding opportunities for solitude." Wilderness need not be completely deserted. There can be other people around – just not too many*." (Freimund and Cole, 2001)

How many Glacier Bay National Park & Preserve visitors can be allowed and still provide a quality experience with opportunities for privacy, solitude, remoteness and unconfined recreation in a primitive and natural setting as mandated in the Wilderness Act? How many visitors are too many? Over the past forty years social scientists have developed a body of research aimed at defining the issues surrounding visitor experience in parks and other outdoor settings. Research and monitoring protocols have been developed for study design and data collection to address visitor satisfaction (Manning, 1986); recreational carrying capacity (Washburne, 1982; Stankey, 1980; Stankey and McCool, 1984; Stankey and Lime, 1973; Stankey and Manning, N.D.; O'Reilly, 1986; Lindberg and McCool, et al, 1996; Shelby and Heberlein, 1996); crowding and density issues (Ditton, 1983; Manning & Valliere, 2001; Shafer & Hammitt, 1995); and acceptable limits (Roggenbuck, 1993). Social scientists have also developed normative data for application in visitor resource management (Shelby and Vaske, 1991; Whittaker and Shelby, 1988; Shelby, Vaske and Heberlein, 1989; Manning, Lawson, et al, 2002; Manning, Valliere, et al 1999; Heywood, Manning et al, 2002). The annotated bibliography reviews pertinent literature from these sources and others (McCool, 2001) reflecting the best available scientific thinking in the field of use limits in outdoor recreation settings.

Several books comprehensively discuss the application of social science research (Manning, 1986) and social impact assessment (Carley & Bustelo, 1984; USDOI-NOAA, 1994) in outdoor recreation management. An excellent summary of guidelines for public use measurement and reporting at parks and protected areas is provided by the World Conservation Union (Hornback and Eagles, 1999). An additional body of work explains the importance of and proper protocols for monitoring visitor management in parks and other outdoor settings once research has been conducted and a management framework has been implemented (Mergliano, 1989; Eagles et al, 2002; Martin, 1989; and Watson, 1989).

Proceedings from several important scientific conferences provide further understanding of visitor experience issues and the research which investigates them. Notable among these conferences is Managing America's Enduring Wilderness Resource (Lime, 1990); Wilderness Science in a Time of Change

Conference (Cole et al, 2000; McCool, 2000); and Visitor Use Density and Wilderness Experience (Freimund and Cole, 2000).

Visitor use studies in Glacier Bay provide data on use patterns and visitor opinions over the past twenty years (Johnson, 1985; Littlejohn, 2000; Manning et al, 1996; and Salvi and Johnson, 1985). Salvi and Johnson (1985) collected visitor use data for application in the development of a backcountry management plan. Study results include sociodemographic characteristics; camper trip characteristics; evaluation of backcountry trips; opinions regarding management issues; perceptions of crowding; evidence of humans; sightings of other vessels and parties; disturbance of craft; and wildlife encounters. Johnson (1990) surveyed tour boat passengers regarding trip motivation, visitor enjoyment, expectations, preferences, effects of watercraft and aircraft sightings on enjoyment, wildlife sightings and trip satisfaction. Manning et al (1996) investigated norm congruence of tour boat passengers regarding evaluations of watercraft and aircraft sightings. Littlejohn (2000) provides data on Bartlett Cove visitor profiles, activities and opinions. Respondents' incidental comments are also included and provide illuminating insight into issues of concern.

Recently, synthesis of this body of research has resulted in several very useful studies addressing wilderness visitor experience research design in general and Alaska national park visitor experiences in particular (Glaspell et al, 2001; Glaspell et al, 2003; Kneeshaw, 2004). These references combine state-of-the-art science with an understanding of the resource management issues facing park administrators. Their focus is on identifying the quality attributes which characterize visitor satisfaction.

Collectively, this field of study provides a wealth of precedent and protocol to draw upon when framing questions and designing studies to address visitor experience issues in Glacier Bay National Park & Preserve. The complex and multi-faceted nature of the visitor experience in this unique park wilderness setting provides significant challenge in the design of useful research and monitoring studies. Principle among the questions which need to be asked is how an encounter with one or more cruise ships affects the non-cruise ship visitor experience in Glacier Bay. Additionally, the question of cruise ship impacts to other cruise ship visitors should be explored. Documentation of impacts to visitor experience attributes using standard state-of-the-art research methods will reveal significant information and allow meaningful conclusions for direct application in the chosen park management framework.

Park Planning and Management

"*People visit parks with goals in mind. These goals are highly personal, but in mass also represent societal goals. It is important that park planners and managers understand the intentions of visitors*." (Eagles and McCool, 2002*)*

As with the measuring and monitoring of visitor experience in protected areas, well-developed processes and frameworks exist to address the management of visitor experience in protected areas, once the interests of park visitors are understood. This section reviews literature which can be used in planning for and managing Glacier Bay visitor experience. The selection of a management framework has implications for the type of visitor experience data to be collected.

One of the earliest management frameworks for outdoor recreation, the Recreational Opportunity Spectrum (ROS), has been used by the Forest Service to manage a broad range of opportunities and activities (Clark and Stankey, 1979; USDA-Forest Service, 1982). Although ROS is capable of addressing the geographical allocation of recreational activities and facilities, it may not be able to address some of the issues of visitor experience quality which protected areas managers face today in Glacier Bay.

The concept of social carrying capacity, borrowed from principles of ecosystem management, was first applied to the management of national parks in the 1960s (Manning, 1996; Manning et al, 1996). The Limits of Acceptable Change (LAC) planning system (Stankey et al 1985; Cole and Stankey, 1998; McCool, 1996; McCool and Cole, 1997) and its derivative system the Visitor Experience and Resource Protection (VERP) planning process (Manning et al 1995) were developed to refine the concept of social carrying capacity for use in managing park visitors. Subsequently, The Protected Area Visitor Impact Management (PAVIM) framework (Farrell and Marion, 2002) has been used to manage visitor experience in parks as well.

Planning and management of tourism in national parks is comprehensively addressed in Eagles and McCool (2002). This reference explains not only ROS, LAC, and VERP, but also the Visitor Activity Management Planning (VAMP) framework; Visitor Impact Management (VIM); and the Tourism Optimization Management Model (TOMM). This reference provides a very useful one-stop guide to state-of-the-art park planning and management tools. Other useful guides for park visitor management planning and management include "Maintaining the Quality of Park Resources and Visitor Experiences – A Handbook for Managers" (Anderson et al, 1998) and "Protected Area Planning Principles and Strategies" (Borrie et al, 1998). All of these park management guidelines, processes, and frameworks emphasize the fact that managing visitor experiences and impacts is a challenging, complex task requiring adequate resource data and a systematic public decision-making process to achieve durable, successful management solutions (McCool, 2002).

The application of these planning principles and frameworks is well represented in the literature. Alaska national parks use best management principles to manage wilderness experiences (Lawson and Manning, 2002). Other national parks around the world offer similar examples (Broom and Valentine, 1995; Harriott, 2002; Higham, 1998; Shafer and Inglis, 2000). Additional sources

discuss the challenge of managing tourism in protected areas (McCool, 2002; Bosselman et al, 1999; Eagles and McCool, 2000; Getz, 1983). A single reference (Johnson, 2002) discusses the concept of environmentally sustainable cruise tourism.

As with measuring and monitoring visitor experience in protected areas, several conferences and workshops have provided highly useful proceedings authored by leaders in the field of park planning and management. These conferences, include Managing America's Enduring Wilderness Resource (Lime, 1990); Wilderness Science in a Time of Change (McCool et al, 2000); and Defining Wilderness Quality: The Role of Standards in Wilderness Management (Shelby et al, 1992).

The field of park planning and management offers excellent tools, processes, framework options, and case studies for successful management of visitor experience in Glacier Bay National Park & Preserve. But visitor experience can only be successfully planned for once essential visitor experience data is in hand. Here it is important to stress the interactive nature of research and management. A planning framework can help formulate the research design needed to provide necessary data.

CRITICAL GAPS

Critical data gaps exist at both the qualitative and quantitative levels. Qualitative data on the visitor experience provides an important understanding of the meanings that visitors associate with Glacier Bay and their experience in the park. Some Glacier Bay visitor use surveys have solicited information regarding various aspects of the visitor experience. This information is reviewed in the Measuring and Monitoring section. However, the data is not comprehensive and leaves many aspects of the visitor experience as detailed in the Visitor Experience section uninvestigated. Incidental anecdotal information is available in the form of visitor comments offered at the end of questionnaire surveys; however, visitors have never been comprehensively surveyed regarding cruise ship encounters.

Quantitative data (e.g. encounter rates) is traditionally used in indicator-based planning frameworks, in writing management prescriptions, and in monitoring impacts. With the exception of Manning et al, 1996 and Johnson, 1990, this data is not currently available as it pertains to park visitor/cruise ship encounters. And while it needs to be collected and will be useful, it can also miss the larger significance and value of the park/wilderness experience. Combining qualitative and quantitative approaches to visitor experience research can lead to a greater understanding and better stewardship of park values.

Table 2 identifies visitor experience attributes, as described in the scientific research and management literature, which have been ascribed to park and

wilderness visits. Table 3 is a list of the potential impacts to backcountry experience from cruise ship visits as discussed in the Glacier Bay National Park & Preserve Environmental Impact Statement (USDOI-NPS, 2003) Research into cruise ship impacts (Table 3) on visitor experience attributes (Table 2) in Glacier Bay National Park & Preserve is absent and needs to be collected before management prescriptions which meet park and wilderness mandates can be developed.

Table 2. Visitor Experience Attributes in Wilderness

Natural/Primitive
Remote
Unconfined
Solitude
Privacy
Spiritual
Freedom of Choice
Self-Reliance
Challenge of Access
Wildlife Encounters

Table 3. Potential Cruise Ship Impacts to Visitor Experience

Biophysical Conditions

Noise Disturbance
Visual Disturbance
Air Pollution
Water Pollution
Wildlife Encounters

Social Conditions

Congruity/Appropriateness
Crowding/Competition
Visitor Safety/Navigation

Park Management Conditions

Number/Frequency/Location of Cruise Ships in Glacier Bay

DIRECTIONS FOR FUTURE RESEARCH AND MANAGEMENT

Visitor experience research and visitor experience management are interactive disciplines. Selection of a visitor management framework will dictate the need for specific types of data, while visitor experience research will reveal the need for management attention to specific issues.

Management: A management framework for Glacier Bay National Park & Preserve needs to be identified. How will data on cruise ship impacts to visitor experience be applied?

Research: Research is needed on the following questions:

- How does the presence of one or more cruise ships affect the experience of other visitors in Glacier Bay?
- What conditions are required for visitor satisfaction in Glacier Bay?
- What are acceptable limits of cruise ship density/crowding in Glacier Bay?

The answers to these questions will allow park managers to develop predictive models to guide management decisions regarding appropriate cruise ship limitations. Visitor experience studies in other Alaska national parks (Kneeshaw et al, 2004; Glaspell et al, 2003) offer excellent models of inquiry and can serve as a point of departure for this research.

CONCLUSIONS

Visitor experience research is a well-developed field and there is ample precedent for work examining the nature of park and wilderness visitor experiences and the impact of one user group on another. An extensive body of social science literature addresses visitor experience in a wide spectrum of outdoor settings, including national parks and wilderness areas. The themes of compatibility, conflict among park users, and social carrying capacity have been researched in a number of settings and among many different user groups and activities. These studies have application to Glacier Bay. Furthermore, research methodologies and planning frameworks exist which can be readily adopted for use in addressing visitor experience issues in Glacier Bay.

An extensive search of the field has revealed a handful of studies (Salvi and Johnson, 1985; Manning et al, 1996; Johnson 1990; Littlejohn, 2000) of visitor use and visitor experience in Glacier Bay. These studies provide preliminary indications of the possible impacts of cruise ships on visitor experience in Glacier Bay; however, they are not comprehensive or conclusive in their findings. The literature search found no studies investigating impacts on visitor experience from the presence of cruise ships in other, analogous, settings. The interaction and impacts of cruise ships on the visitor experience of other park visitors

(backcountry, private vessel, charter boat, and tour boat visitors) in Glacier Bay is an unexplored arena and needs to be investigated.

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I thank Glacier Bay Scientific Advisory Board Representatives Dr. Robert F. Schroeder and Dr. Lee K. Cerveny for their guidance, advice, support and enthusiasm in addressing this important and complex issue.

ANNOTATED REFERENCES

Anderson, D. H., D. W. Lime, et al. (1998). Maintaining the Quality of Park Resources and Visitor Experiences - A Handbook for Managers. St. Paul, Minnesota, Cooperative Park Studies Unit Department of Forest Resources University of Minnesota.

> **Park Planning and Management.** *Abstract: The handbook stimulates the informed consideration of a range of options to address unacceptable use-related impacts to resources and visitor experiences. It doe this by stimulating critical thinking and in-depth discussion of a range of strategies and tactics. The handbook provides information that can help managers assess strategies and tactics in light of both general and site-specific factors.* This reference provides a step-by-step explanation of the park management planning process, subsequent implementation and monitoring. Its most direct contribution to the issue of visitor experience in Glacier Bay National Park & Preserve is a list of visitor experience impacts as follows:
> - *unacceptable levels of crowding at attraction sites;*
> - *visitor conflicts due to incompatible uses, encounters with large groups or parties dissimilar to one's own...., visitor displacement (spatial, temporal, or total)*
> - *noncompliant behavior*
> - *inadequate or inappropriate levels of access*
> - *threats to visitor safety*
>
> The handbook has direct applicability in addressing visitor experience planning issues and moderate usefulness regarding the issues of most concern in Glacier Bay. **Applicability: Moderate.**

Borrie, W. T., S. F. McCool, et al. (1998). Chapter 6 Protected Area Planning Principles and Strategies. Ecotourism - A Guide for Planners and Managers Vol. 2. K. Lindberg, M. E. Wood and D. Engeldrum. North Bennington, Vermont, The Ecotourism Society**:** 133-154.

> **Park Planning and Management.** This chapter presents the Limits of Acceptable Change (LAC) concept for application in the management of

protected areas. It also explains the Tourism Organization Management Model (TOMM) developed in Australia and concludes, "*The Limits of Acceptable Change planning process, and its derivative approaches like TOMM, represent an effective evolution of problem conceptualization compared to the recreational carrying capacity approach. However, in and of itself, LAC provides only a framework for identifying appropriate management actions. It does not determine what should be done, by whom, or where managerial, public and scientific expertise is still required. LAC helps frame management questions more effectively than in the past. Understanding the principles upon which LAC is based, and the conditions under which visitor management of protected areas must operate, will help lead to planning systems more compatible with specific agency needs and capability, and more suited to the complexities of protected area planning in this era of social and political change."*

The major relevant finding of this chapter is the explanation of the use of the LAC concept in framing management questions. This approach can have direct application to the issue of the quality of the visitor experience in Glacier Bay. The reference is an authoritative explanation of LAC written by ranking experts in the field. The limitations of LAC are identified. LAC can be used as a statement of principles from which a more tailored planning approach can be developed. This reference can be used to begin addressing management of visitor experience is therefore of moderate applicability in addressing the visitor experience issue in Glacier Bay. **Applicability: Moderate.**

Bosselman, F. P., C. A. Peterson, et al. (1999). Managing Tourism Growth. Washington DC, Island Press.

Park Planning and Management. The "*overall purpose of this book is to analyze and evaluate methods by which communities can successfully "tame" tourism by carefully managing its growth so that it brings to the destination community the benefits the community wishes and minimizes the impacts that the community deems harmful."* The focus of this book is more on community rather than park management. However, Chapter 5 Quantity Management Strategies offers some ideas with application to Glacier Bay National Park & Preserve and adjacent communities, including the following: *While neither LAC nor VIM was developed with tourist settings in mind, both systems have influenced much of the current thinking about quantity management in tourism destinations. Both consider the social impacts of tourism, although they stress the visitors' experience rather than that of the host community. Both insist on the identification of measurable objectives so that success in reducing unwanted impacts can be accurately assessed. Both build on a carrying capacity framework but seek techniques that are different from the imposition of numerical limitations. Both insist on the importance of*

continued monitoring to ensure that management strategies are having the desired effects."

Major relevant findings of this reference are focused on community management of tourism. With the emphasis on host community impacts rather than visitor experience, it may be a more useful resource for communities adjacent to Glacier Bay. The applicability to Glacier Bay visitor experience issues is relatively low. **Applicability: Low.**

Broome, G. and P. Valentine (1995). Principles of Social Impact Assessment and Its Application to Managing the Great Barrier Reef. CRC Reef Research Centre Technical Report. Townsville, CRC Reef Research Centre**:** 74.

Park Planning and Management. This report combines Social Impact Assessment methodology and recreation management frameworks to address visitor management in the Great Barrier Reef (GBR). Three recent studies of visitor experiences on the GBR are reviewed, a bibliography of social impact assessment and recreation management is presented, and an extensive list of public participation methodologies is reviewed. This reference provides a useful insight into visitor experience issues and management strategies in a marine park, but does not address the issue of cruise ship impacts on the Great Barrier Reef. **Applicability: Low.**

Buckley, R. (2000). Tourism and Wilderness: Dancing With the Messy Monster. Wilderness Science in a Time of Change Conference, Missoula, MT, USDA Forest Service, Rocky Mountain Research Station.

Park Planning and Management. *Abstract: Currently, tourism offers one of the best prospects for conserving remaining areas of unprotected wilderness in most parts of the world. Tourism produces environmental impacts, and in heavily-visited protected areas these impacts may be a significant threat to conservation values and a major management issue; along with other anthropogenic impacts such as weeds, pests, pathogens, and pollution. The impacts of tourism are generally far less than those of other industry sectors such as forestry, farming, mining or commercial fisheries, however, so if tourism can displace these land uses, there is a net gain for wilderness despite the impacts of tourism itself. Tourism is not an ideal tool for conservation, but in most of the world, and at least in the short term, it is perhaps the only one with sufficient political and economic clout to be effective.*

The human economy behaves like a rather messy monster which creates impacts on the global environment not only by consuming raw materials and excreting waste products, but by accidental damage caused through messy habits, clumsiness and inattention. The monster's size is

increasing much faster than its manners, and its tentacles are probing further into every corner of its habitat. Using tourism and recreation as a tool for wilderness conservation is like dancing with the messy monster in a crowded cage: risky, but unavoidable.

The major relevant finding of this article is its identification of tourism as a political and economic engine that park management must live with. This describes the issue of cruise ship tourism in Glacier Bay quite well, however, the reference does not present a management framework or system to reconcile the problems and issues raised by tourism in parks and therefore has low applicability to addressing the visitor experience issue in Glacier Bay. **Applicability: Low.**

Carley, M. and E. Bustelo (1984). Social Impact Assessment and Monitoring: A Guide to the Literature. Boulder and London, Westview Press.

Measuring and Monitoring. This guide to the literature addresses cross-disciplinary aspects of social impact assessment (SIA) issues, problems and methods. Part I provides an historical overview to the origins and focus of both objective and subjective conditions affecting social impacts. It presents a discussion of general methodologies and approaches to social impact assessment and monitoring and provides case studies. Part II discusses the integration of SIA with Environmental Impact Assessment. Of particular interest is Chapter 17 Environmental Perception and Landscape Preferences. The discussion of physical environment and its socio-political meaning in this chapter provides useful background when framing the issue of cruise ship impacts on visitors in Glacier Bay National Park & Preserve. However, its dated references do not provide contemporary examples and therefore limit its specific usefulness. Part III addresses social assessment in developing countries. Part IV provides lists of relevant references. **Applicability: Low.**

Clark, R. N. and G. H. Stankey (1979). The Recreation Opportunity Spectrum: A Framework for Planning, Management, and Research, USDA Forest Service Northwest Forest and Range Experiment Station**:** 32.

Park Planning and Management. Abstract: *The end product of recreation management is a diverse range of opportunities from which people can derive various experiences. This paper offers a framework for managing recreation opportunities based on six physical, biological, social, and managerial factors that, when combined, can be utilized by recreationists to obtain diverse experiences.*

The use of the Recreation Opportunity Spectrum framework to address changing distribution of recreation opportunities through time is discussed. It is concluded that routine collection of sufficient baseline information is

required to monitor changes and make appropriate management decisions. The paper presents a high quality expert analysis by two of the authors of the Recreation Opportunity Spectrum management framework. It has direct applicability to management of recreation opportunities in Glacier Bay but is of only moderate value in addressing visitor experience issues which deal with the meaning of wilderness. **Applicability: Moderate.**

Cole, D. N. (1994). The Wilderness Threats Matrix: A Framework for Assessing Impacts, USDA Forest Service Intermountain Research Station.

Measuring and Monitoring. From the Research Summary: *This report proposes a comprehensive framework for assessing threats to wilderness. The framework can be depicted as a matrix with potential threats to wilderness as columns and wilderness attributes intended for preservation as rows. Cells in the matrix represent the impacts of each threat on each attribute.*

The most generally significant threats to wilderness are recreational use and its management, livestock grazing and its management, mining, fire and its management, exotic species introductions and invasions, water projects, atmospheric pollutants, and practices on adjacent land. The primary wilderness attributes of concern are air, aquatic systems, rocks and landforms, soils, vegetation, animals, ecosystems and landscapes, cultural resources, and opportunities for wilderness experiences.

The threats matrix will help wilderness planners, managers, and researchers. It can be used by planners during the scoping process, in describing the current management situation, in developing assumptions about the future, and in assessing the impacts of alternative management actions. It provides a comprehensive overview of monitoring needs. It can be used to assess research and management priorities for individual wildernesses, regions, and the National Wilderness Preservation System.

The matrix was used to assess threats to wildernesses in the Forest Service's Northern Region (northern Idaho and Montana). The significance of and knowledge about threats were assessed by a team of wilderness experts. The most significant perceived threat was fire and its management; aquatic systems were the wilderness attribute considered to be most threatened. The difference between significance and knowledge was greatest for fire and its management, suggesting that this is the threat most in need of further research. Ecosystems, landscapes, and aquatic systems are the wilderness attributes most in need of further research.

This planning tool presents a highly useful framework for identifying and evaluating environmental and social threats to wilderness and wilderness

experience. It provides a comprehensive threat analysis authored by a leading researcher in the field of wilderness management. The Wilderness Threats Matrix has direct applicability to the issue of visitor experience in Glacier Bay National Park & Preserve. It provides a useful method of highlighting the issues to be addressed. **Applicability: High.**

Cole, D. N. (1997). "Solitude: Researchers Continue to Delve into Solitude Component of Wilderness." Signpost for Northwest Trails **January 1997**: 33-34.

Measuring and Monitoring. This guest editorial offers a useful discussion regarding the meaning of solitude in wilderness and the effect of encounters on the visitor experience. The author states, "*Most visitors state that they will accept or tolerate several times as many encounters as they prefer. While few would question this general conclusion, some researchers (myself included) question the validity of quantitative estimates of acceptable numbers of encounters.... Until they experience a truly unacceptable number of encounters (and perhaps even after such an experience), this may not be possible."*

The major relevant finding of this reference is its exploration of the attribute of solitude in wilderness as an important aspect of the visitor experience. This paper has useful application and high applicability when considering solitude and the visitor experience in Glacier Bay. **Applicability: High.**

Cole, D. N. and G. H. Stankey (1998). Historical Development of Limits of Acceptable Change: Conceptual Clarifications and Possible Extensions. Limits of Acceptable Change and Related Planning Process is: Progress and Future Directions: 1997 May 20-22; Missoula, Montana, Missoula, Montana, USDA Forest Service Rocky Mountain Research Station.

Park Planning and Management. *Abstract: The Limits of Acceptable Change (LAC) process was developed to deal with the issue of recreational carrying capacity. For that purpose, the LAC process sought to explicitly define a compromise between resource/visitor experience protection and recreation use goals. The most critical and unique element of the process is the specification of LAC standards that define minimally acceptable conditions. This paper identifies the antecedents of LAC, describes the rationale behind its formulation, and attempts to clarify LAC terminology and concepts. It assesses the extent to which a more generic LAC process might be applied to issues beyond recreation management in wilderness.*

The major relevant finding of this paper is an historical review of LAC and its applications. It is authored by experts in the field and identifies limitations of the LAC planning framework. It is moderately useful if LAC

is used in developing a planning framework for the Glacier Bay visitor experience. **Applicability: Moderate.**

Cole, D. N., S. F. McCool, et al. (2000). Changing Perspectives and Future Directions. Wilderness Science in a Time of Change, Missoula, MT, USDA Forest Service Rocky Mountain Research Station Ogden, UT.

Measuring and Monitoring. Abstract: *Ten papers presented as plenary talks at the conference, "Wilderness Science in a Time of Change," are included. Topics include: the influence of global change on wilderness and its management; contemporary criticisms and celebrations of the wilderness idea; the capacity of science to meet the challenges and opportunities wilderness presents; wilderness in relation to biological conservation and the human experience of wilderness; and fundamental dilemmas of wilderness management.*

A paper by Cole and Hammitt "Wilderness Management Dilemmas: Fertile Ground for Wilderness Management Research" explores the conflicts among naturalness, solitude and wildness. It concludes with recommendations for increased scientific knowledge and a tempered enthusiasm for naturalness. The paper is authored by long time experts in the field and has direct applicability to Glacier Bay visitor experience research. It has only moderate usefulness, however, because conflicts over naturalness is not the primary issue facing visitor management in Glacier Bay. **Applicability: Moderate.**

Cole, D. N., S. F. McCool, et al. (2000). Wilderness Visitors, Experiences, and Visitor Management. Wilderness Science in a Time of Change Conference, Missoula, MT, USDA Forest Service Rocky Mountain Research Station.

Measuring and Monitoring. *Abstract: Thirty-seven papers are presented on wilderness visitors, experiences, and visitor management. Three overview papers synthesize knowledge and research about wilderness visitors, management of visitor experiences, and wilderness recreation planning. Other papers contain the results of specific research projects on wilderness visitors, information and education, and visitor management.*

Major relevant papers include Manning and Lime "Defining and Managing the Quality of Wilderness Recreation Experiences" and Watson "Wilderness Use in the Year 2000: Societal Changes That Influence Human Relationships with Wilderness". Manning and Lime review wilderness recreation management frameworks including ROS, LAC, VIM, VERP and the concept of carrying capacity. The authors survey the significant body of literature addressing wilderness management and conclude with research recommendations and suggested management

directions. The authors are leading researchers in this field and present a comprehensive and commanding survey of the field. The Watson paper reviews changing trends, values, and attitudes regarding wilderness use and recommends future research on wilderness visitors. The paper updates and extends an earlier synthesis of wilderness visitor experience knowledge by this expert in the field. The recommended research on wilderness visitors highly useful and has direct applicability to Glacier Bay. **Applicability: High.**

Cole, D. N. (2000). "Natural , Wild, Uncrowded, or Free: Which of These Should Wilderness Be?" International Journal of Wilderness **6**(2): 5-8.

Park Planning and Management. *Abstract: The most important and desirable attributes of wilderness are that it is natural, wild, uncrowded, and free. However, these attributes come into conflict with each other as society faces difficult decisions about wilderness management. This article discusses these attributes, ultimately suggesting that the value of wilderness might be optimized by embracing a diverse wilderness system, a system in which wilderness values are maximized or minimized in different areas.*

The major relevant finding in this article is identifying the conflicts inherent in managing for multiple values in the same wilderness area. Issues of visitor experience in Glacier Bay face some of these same conflicts and challenges. **Applicability: Moderate.**

Cole, D. N. and T. C. Daniel (2003). "The Science of Visitor Management in Parks and Protected Areas: from Verbal Reports to Simulation Models." Journal of Nature Conservation **11**: 267-277.

Measuring and Monitoring. *Abstract: Visitor management in parks, wilderness and other protected areas requires information about visitor-environment interactions and, particularly, the distribution and flow of visitors in space and time. Such information is usually sketchy and based largely on the verbal reports of visitors. A review of recent psychological and neurological research and theory suggests that traditional verbal survey methods cannot in principle provide an adequate basis for models of human landscape navigation. We argue for more use of direct observation of visitor movements and the utility of travel simulation models. Simulation modeling of visitor flow can be helpful in making monitoring programs more efficient, in fine-tuning existing management programs, and in assessing the likely consequences of alternative future scenarios. We review early efforts to simulate the flow of recreation use, describe several current modeling efforts and conclude with suggestions for a research and development effort.*

The major relevant finding of this paper is its focus on the study of visitor use (travel patterns and recreation activities). It does not address other aspects of the visitor experience. **Applicability: Moderate**

Cole, D. N. (2004). "Wilderness Experiences - What Should We Be Managing For?" International Journal of Wilderness **10**(3): 25-27.

Park Planning and Management. From the Conclusion: *Monitoring wilderness character and managers' success in meeting stewardship objectives are important. Monitoring of setting attributes that are subject to managerial control and related to desired wilderness experiences seems to provide a better basis for assessment than measures of the wilderness experience itself or of visitors' evaluations of the experience. However, our ability to select good indicators of the setting will clearly increase as we learn more about the nature of human experience in wilderness and how that experience varies with setting attributes. In addition, visitor evaluations and opinions about appropriate setting attributes, along with those of other stakeholders, need to be considered when setting management objectives.*

This highly useful article on the relationship between biophysical, social and managerial conditions and the visitor experience offers a relevant discussion that can be very helpful in framing management questions for Glacier Bay. The major relevant finding of this article is the importance of identifying good indicators to monitor visitor experience and setting attributes. The author presents a conceptual model of the relationship between setting attributes, the personal characteristics of visitors, their experiences, and their evaluation of those experiences. The paper has high applicability to the Glacier Bay visitor experience. **Applicability: High.**

Ditton, R. B., A. J. Fedler, et al. (1983). "Factors Contributing to Perceptions of Recreational Crowding." Leisure Sciences **15**(4): 272-288.

Measuring and Monitoring. *Abstract: This paper examines perceptions of crowding in a river recreation setting, using an alternative to the conventional crowding measure and a diverse set of potential predictor variables that have not been examined concurrently in previous studies. Analysis focuses on differences between three groups of respondents: crowded floaters, whose enjoyment was reduced by encounters with other people; neutral floaters; and those floaters whose enjoyment was increased by the visitor density they encountered. Findings support some previous arguments that crowding is related more to visitors' expectations, preferences, and previous experience than to actual or perceived encounter levels. Further, perceptions of crowding were found to be related to encounter expectations and preferences at specific river*

locations (e.g. at put-in and rapids) and to perceptions of other aspects of trip quality.

Perceptions of crowding in Glacier Bay National Park & Preserve have a direct bearing on the quality of visitor experience. This study provides a useful discussion of perceived crowding when seeking to understand the issue in Glacier Bay. **Applicability: Moderate.**

Eagles, P. F. J., S. F. McCool, et al. (2002). Monitoring Tourism in Protected Areas. Sustainable Tourism in Protected Areas: Guidelines for Planning and Management. Gland, Switzerland
Cambridge, UK, IUCN**:** xv+183.

Measuring and Monitoring. This overview document presents state of the art techniques for managing tourism in protected areas. It explains the protected area planning process and describes implementation tasks to keep tourism sustainable in protected areas. Most useful to the issue of visitor experience in Glacier Bay National Park & Preserve is Chapter 11 Monitoring Tourism in Protected Areas. This chapter outlines the characteristics of a monitoring system and presents The Nature Conservancy Monitoring Guidelines. Also useful is Appendix D presenting a comparison of five visitor management frameworks (LAC, VIM, VERP, VAMP, ROS). **Applicability: High.**

Eagles, P. F. J., S. F. McCool, et al. (2002). Tourism in National Parks and Protected Areas - Planning and Management. New York, NY, CABI Publishing.

Park Planning and Management. *Abstract: The central goal of this book is to describe the state-of-the-art of tourism planning and management in national parks and protected areas. A secondary objective is to provide guidelines for best practices in tourism operation."*

Because of the global perspective, this book provides a good overview of park management issues pertaining to tourism including the following chapters most relevant to providing background information on the issue of visitor experience in Glacier Bay National Park & Preserve: Chapter 5 Management of Visitors in National Parks and Protected Areas; Chapter 7 Monitoring of Tourism in National Parks and Protected Areas; Chapter 10 Tourism in Marine Protected Areas. Management tools, including Visitor Management Systems (LAC, VIM, VERP, VAMP, and TOMM) and the Recreation Opportunity Spectrum are described. This reference provides a good, contemporary overview of park management issues and processes. Although useful for its comprehensive focus, the specific, unique visitor experience issues faced in Glacier Bay among cruise ship and non-cruise ship visitors are not addressed. **Applicability: High.**

Farrell, T. A. and J. L. Marion (2002). "The Protected Area Visitor Impact Management (PAVIM) Framework: A Simplified Process for Making Management Decisions." Journal of Sustainable Tourism **10**(2): 31-51.

> **Park Planning and Management.** This paper proposes the Protected Area Visitor Impact Management (PAVIM) framework as an alternative to carrying capacity and other frameworks such as Limits of Acceptable Change. Positive attributes of PAVIM, include simplicity, flexibility, cost effectiveness, timeliness, and incorporating input from stakeholders and local residents. Negative attributes include diminished objectivity and cultural sensitivity issues. The PAVIM framework is a new, simplified management process as yet untested in the field. It has some applicability to visitor experience issues in Glacier Bay but low to moderate usefulness because it does not allow the adequate consideration of visitor experience impacts nor does it require associated monitoring and standards of other frameworks. **Applicability: Moderate.**

Fox, K. (2000). Navigating Confluences: Revisiting the Meaning of "Wilderness Experience". Wilderness Science in a Time of Change Conference, Missoula, MT, USDA Forest Service, Rocky Mountain Research Station.

> **Park Planning and Management.** *Abstract: Concepts of wilderness and "wilderness experience" merge into a grand or meta-narrative that describes how "wilderness experience" is and provides a normalized reference point for values, beliefs, actions, and choices. This paper engages and juxtaposes critiques by scholars and authors representing non-dominant perspectives with the North American, wilderness meta-narrative. The bricolage analysis develops a repleteness of interpretation, feeds new visions from the margin to the center, and enhances a particular style of ethical discourse.*
>
> The major relevant finding of this paper is its exploration of the meaning and significance of the wilderness experience. It explores the possibilities of changing or evolving meaning through time. The paper does not present or recommend a planning framework in which to address the meaning of wilderness. It raises questions applicable to the issue of cruise ships and the visitor experience in Glacier Bay as it relates to the meaning of wilderness and a wilderness experience, but does not offer useful approaches for addressing the issue and is therefore of limited (moderate) applicability. **Applicability: Moderate.**

Freimund, W. A. and D. N. Cole (2001). Visitor Use Density and Wilderness Experience: Proceedings 2000 June 1-3, Missoula, MT, USDA Forest Service Rocky Mountain Research Station.

Measuring and Monitoring. *Abstract: The workshop was convened to assess progress and offer further ideas regarding scientific contributions to (1) understanding relationships between visitor use density and wilderness experiences and (2) applying such knowledge to decisions about use limitation in wilderness and parks. The first paper provides an overview of the topic and the papers presented at the workshop. Subsequent papers include reviews of previous research, discussion of issues related to use limitation, exploration of the solitude concept and of visitor conflict, and explications of alternative research methodologies.*

Major relevant findings of this workshop include a paper by Borne and Birzell "Approaches to Measuring Quality of the Wilderness Experience" in which literature addressing four approaches to measuring wilderness experience are reviewed: satisfaction, benefits-based, experience-based, and meanings-based approaches. The study is directly applicable to Glacier Bay and issues of visitor experience and can be highly helpful in addressing use limits in time and space. The study concludes that a linear and direct relationship between use density conditions and experimental quality should not be assumed. **Applicability: High.**

Getz, D. (1983). "Capacity to Absorb Tourism - Concepts and Implications for Strategic Planning." Annals of Tourism Research **10**: 239-263.

Park Planning and Management. *Abstract: The concept of capacity to absorb tourism has received considerable attention but measures of capacity have seldom been applied to tourism plans. This void can be attributed to varying interpretations of the meaning of capacity, the complexity of assessing and predicting impacts, and opposition to the imposition of limits on growth. In this paper, different interpretations of tourism capacity are discussed, including inherent assumptions and potential applications. It is concluded that the concept can best be applied in a systematic planning process which includes no apriori assumption of optimality or ultimate limits on growth or change. A strategic planning model is recommended which includes the establishment of goals, ongoing evaluation of impacts, and the optional use of limits.*

The major relevant finding of this article is the recommendations of strategic planning for tourism using goals, evaluation of impacts and possible use limits. It can be applied to the issue of planning for cruise ships in Glacier Bay but has relatively low applicability to the Glacier Bay visitor experience issue because of its dated, general approach and lack of focus on the wilderness/park management context. **Applicability: Low.**

Glaspell, B. and A. Puttkammer (2001). Linking Wilderness Research and Management - Volume 2 Defining, Managing and Monitoring Wilderness Visitor

Experiences: An Annotated Reading List. Gen. Tech. Rep. V. Wright. Fort Collins, CO, USDA Forest Service, Rocky Mountain Research Station**:** 29.

> **Measuring and Monitoring.** *Abstract: Opportunities for unique visitor experiences are among the defining attributes of wilderness. In order to understand and protect these experiences, natural and social scientists have pursued an ever-expanding program of wildland recreation research. While much of the early research sought to identify simple relationships between setting attributes and visitor experiences, recent research efforts have expanded to address the values people hold for wilderness (including nonrecreation values), a variety of types and dimensions of wilderness experiences, and factors that influence those experiences. Whereas early wilderness stewards had few resources other than instinct and personal experience to guide them, managers today have access to a significant body of literature related to defining, managing, and monitoring wilderness experiences. This reading list represents a sample of this information and is organized in a way that is intended to be useful to both managers and researchers. Section I contains both philosophical and empirical papers that address values related to wilderness and wilderness experiences. Section II contains papers that describe wilderness experiences and specific dimensions of those experiences. Section III has references that describe influences on wilderness experiences and approaches to managing them. Section IV addresses long-term wilderness planning and monitoring.*
>
> This highly useful annotated bibliography provides references regarding the research and management of visitor experience and can serve as a resource for Glacier Bay National Park & Preserve. **Applicability: High.**

Glaspell, B., A. Watson, et al. (2003). "Selecting Indicators and Understanding Their Role in Wilderness Experience Stewardship at Gates of the Arctic National Park and Preserve." The George Wright Forum **20**(3): 59-71.

> **Measuring and Monitoring.** This article addresses the use of both qualitative and quantitative data regarding visitor experience dimensions in Gates of the Arctic wilderness. A qualitative approach is helpful when little is known about the nature of the wilderness experience and in understanding the meaning visitors assign to their wilderness experience. Quantitative research is events focused and provides predictive knowledge used by indicator-based planning frameworks. Using a combined approach provides a more durable approach to identify unique qualities of wilderness experience and the dynamic experience of wilderness visitors. **Applicability: High.**

Hammitt, W. E. (1982). "Cognitive Dimensions of Wilderness Solitude." Environment and Behavior **14**(4): 478-493.

Visitor Experience. This article seeks to develop a framework for investigating the meaning of wilderness solitude. Major relevant findings include proposal of a definition of wilderness solitude as *"a form of privacy in a specific environmental setting where individuals experience an acceptable degree of control and choice over the type and amount of information they must process."*

The investigator used a self-administered survey questionnaire of wilderness campers to investigate the experience of wilderness solitude. This study used standard survey design and statistical analysis to establish data results and derive conclusions. It has high applicability to issues of visitor experience in Glacier Bay wilderness. **Applicability: High.**

Hammitt, W. E. (1983). "Toward an Ecological Approach to Perceived Crowding in Outdoor Recreation." Leisure Sciences **15**(4): 309-320.

Visitor Experience. *Abstract: Perceived crowding in outdoor recreation research is generally approached from a sociological or interpersonal basis. The purpose of this paper is to present a conceptual approach to perceived crowding where people/environment interactions are emphasized, rather than social relationships. Crowding is treated as a perceptual reaction to an environmental situation, where environmental constraints interfere with the functioning and task performances desired by an individual. It is postulated that crowding can occur without the presence of others, that it can be the result of functional density and not simply the result of social processes involving the interacting of others*.

Major relevant findings of this study regarding perceptions of crowding as a result of environmental constraints has significant merit and potential applicability to the presence of cruise ships in Glacier Bay waters. A conceptual analysis was employed in review of existing literature to integrate people/environment interactions and functional preferences in development of an ecological approach to the concept of crowding. The paper is limited to a preliminary exploration of the conceptual model proposed and as such has moderate value to the issue of visitor experience in Glacier Bay. **Applicability: Moderate.**

Hammitt, W. E. and G. F. J. Brown (1984). "Functions of Privacy in Wilderness Environments." Leisure Sciences **6**(2): 155-166.

Visitor Experience. *Abstract: Westin (1967), in his Privacy and Freedom, suggests that there are four basic functions of privacy in society (personal autonomy, emotional release, self-evaluations, limited and protected communication). Westin's theoretical model was examined for*

its utility in understanding the functions of privacy in wilderness environments. Importance ratings of 106 wilderness users for 28 scale items which characterized the privacy functions were factor analyzed. The factor analysis yielded five functions instead of Westin's four; however, Westin's model served as a valuable tool for interpreting the functions. "Emotional release" was rated the most important function, while "resting the mind from anxiety and mental fatigue" was the highest rated individual item.

The major relevant finding of this paper draws conclusions regarding the function of privacy in wilderness. The study a survey questionnaire and standard analysis techniques. It has applicability to questions of quality of experience in Glacier Bay wilderness. These findings regarding the function of privacy in wilderness can be highly useful in designing research for Glacier Bay. **Applicability: High.**

Hammitt, W. E. and M. Patterson (1991). "Coping Behavior to Avoid Visual Encounters: Its Relationship to Wildland Privacy." Journal of Leisure Research **23**(6): 225-237.

Visitor Experience. *Abstract: Too many visitor encounters can detract from the privacy sought in wildland environments. Coping behavior to avoid or adjust to visitor encounters is one procedure for reducing encounters and maintaining wildland privacy. This paper examines the degree to which backpackers in Great Smoky Mountains National Park used six physical and six social coping behaviors to avoid encounters/interactions with other backpackers. The influences of solitude importance, encounter norms, and level of backpacker experience on visitor use of coping behaviors were analyzed also. Most respondents used social coping behaviors infrequently, except for reducing social interactions with backpackers in other parties. The importance of solitude to visitors was related significantly to adoption of all six physical coping behaviors but to none of the social coping behaviors. Visitors who had lower encounter norms and who were more sensitive to actual encounters experienced participated significantly more often in 10 of the 12 coping behaviors. Level of past experience had little influence on use of coping behaviors. The findings are interpreted in the context of coping behavior as a means of avoiding or adjusting to visitor encounters in wildland recreation areas. The role that coping behavior may serve to control environmental conditions and desired level of wildland privacy is discussed, also.*

The major relevant finding of this study is that physical coping behaviors are the primary method used to avoid encounters in wildland recreation areas. A questionnaire mail survey was conducted of users of backcountry shelters and trails and standard analysis techniques were

employed. Directions of inquiry regarding wilderness users and cruise ship encounters are suggested; however, the usefulness of the findings and the extent to which they can be generalized are limited because the findings pertain to people/people encounters rather than people/cruise ship encounters. The results have moderate applicability to Glacier Bay and the discussion can be useful in understanding possible methods for mitigating visitor encounter impacts in Glacier Bay National Park & Preserve. **Applicability: High.**

Hammitt, W. E. and W. M. Rutlin (1995). "Use Encounter Standards and Curves for Achieved Privacy in Wilderness." Leisure Sciences **17**: 245-262.

Visitor Experience. *Abstract: The purpose of this study was to investigate the relationship between wilderness use encounters and degree of privacy achieved at three locations within a wilderness. The theoretical perspective of the research was grounded in environmental psychology, which emphasized the dynamic nature of person and situation fit, rather than the sociology of normative behavior. The study depicted privacy as a dependent measure and argued that privacy is not the opposite of perceived crowding. It also suggested that privacy may be a more appropriate dependent variable for encounter studies than those measures used in past recreation research. Privacy was operationalized as "the level of desired privacy achieved," measured on a 10-point scale. It was then compared with level of actual, ideal, and maximum use encounters for 600 users of a South Carolina wilderness area. Results indicated that number of actual group encounters was inversely related to degree of desired privacy achieved, in the hypothesized inverse curve pattern anticipated but never proved for satisfaction research. Encounter-privacy curves for ideal and maximum encounter levels also resulted in predicted pattern. Finally, degree of privacy achieved was negatively affected when ideal and maximum encounters were exceeded by actual encounters, showing a high degree of congruency between theorized and empirical findings.*

A major relevant findings of this paper is that the actual and theoretical degrees of privacy achieved are congruent, thus making it possible to predict impacts to privacy in wilderness from various encounters. A user survey and follow-up mail questionnaire and standard analysis were employed. The study findings can be generalized to other areas and has moderate applicability and usefulness to the issue of visitor experience in Glacier Bay. Its application may be limited by consideration of the different nature of people/cruise ship encounters. This article, by addressing the issue of privacy in a wilderness setting, can be useful in designing visitor experience research in Glacier Bay National Park & Preserve. **Applicability: Moderate**

Harriot, V. J. (2002). Marine Tourism Impacts and Their Management on the Great Barrier Reef. CRC Reef Research Centre Technical Report. Townsville, CRC Reef Research Centre.

Park Planning and Management. From the Conclusion: *The impacts of marine tourism within the Great Barrier Reef Marine Park (GBRMP) are generally localized and of small magnitude compared with those of other environmental concerns (overfishing, inshore water quality, crown of thorns starfish, coral bleaching). Commercial tourism operators have strong motivation to protect the reef resources on which their industry is based. There has been increased emphasis in recent years on involvement of stakeholders including the tourism industry in management of the GBRMP. The status of tourism as one of the "critical issues" in marine park management is justified by the fact that tourism is the major commercial activity with the GBRMP. It generates significant income, supports a large number of employees, and contributes to the reef's World Heritage Values by presenting the reef to tourists and the community. Apart from the local tourism impacts within the Marine Park, which are generally well managed, there has been concern that rapid expansion of tourism can increase pressure for coastal and urban development, with potential indirect and cumulative effects on the GBRWHA.*

This report presents data from surveys addressing public perceptions of marine tourism impacts. It also discusses the impacts, and secondary impacts, of commercial tourism on the Great Barrier Reef. It does not specifically address cruise ship traffic or marine wilderness issues. **Applicability: Low.**

Harrison, R. T., R. N. Clark, et al. (1980). Predicting Impact of Noise on Recreationists, USDA Forest Service**:** 21+ Appendices.

Visitor Experience. From the Forward*: The first part of this reference describes the Outdoor Recreation Opportunity Spectrum (OROS) and how the acceptability of impacts of various influences on natural resources varies as a function of outdoor recreation opportunities at any given site. The second part presents a method of predicting the impact of noise on outdoor recreation - called the system for the Prediction of Acoustic Detectability (SPreAD) - and instructions on how to use SPreAD with examples of its use.*

From the Preface: Efficient and effective forest management depends upon managers having adequate information about impacts on natural resources. One of the most difficult impacts to assess is sound. The impact of a sound depends upon both the physical properties of the sound and the characteristics of the receiver (in our case the human "listener".)

The Project Record portion of this document addresses the problem of quantifying the impact of sound on the forest recreation experience.

This reference could be useful in designing research to determine the effect of the cruise ship generated noise (both engines and P.A. system) on kayakers, hikers and campers in Glacier Bay National Park & Preserve. **Applicability: Low.**

Heywood, J. L., R. E. Manning, et al. (2002). "Normative Research in Outdoor Recreation: Progress and Prospects for Continued Development and Applications." Leisure Sciences **24**(3-4): 251-253.

Measuring and Monitoring. *Abstract: This special issue of Leisure Sciences on Normative Research in Outdoor Recreation grew from on-going research into and theoretical development of normative approaches to social and environmental issues and problems in outdoor recreation. The nine articles included in this special issue provide insights that improve and expand out understanding of norms, their measurement, and utility.*

The major relevant finding of this journal issue is its explanation of normative research measurement and the role it plays as a methodology for recreation management. As experts in the field, the authors offer a high quality analysis which has general applicability and moderate usefulness to Glacier Bay visitor experience issues. **Applicability: Moderate.**

Higham, J. (1998). "Sustaining the Physical and Social Dimensions of Wilderness Tourism: The Perceptual Approach to Wilderness Management in New Zealand." Journal of Sustainable Tourism **6**(1): 26-51.

Park Planning and Management. From the Overview*: The dynamics of the tourism industry are well illustrated by the case of New Zealand's tourism development over the last decade. The number of international tourists visiting New Zealand has doubled in the last ten years to approximately 1.5 million annual visitors. Associated with this growth has been a significant shift in patterns of tourist demand. No longer do most tourists simply comply with established tourist routes linking the high profile scenic attractions. Rather tourists have demonstrated a preference for more independent and dispersed patterns of travel, including an increase in demand for settings that offer subjective qualities of wilderness experience. This poses a complex but intriguing management challenge. If wilderness recreation involves pristine natural settings in the complete absence of facility development and visitor management, then these resources are more prone to degradation than any other natural tourism resource. This paper suggests that an understanding of tourist*

perceptions of wilderness is crucial to the management of wilderness tourism, and considers the application of the perceptual approach to wilderness tourism as a means of sustaining wilderness values while promoting the satisfaction of visitor expectations.

This article examines the wide range of opinion regarding solitude in wilderness and concludes that more research is needed on the subject. The usefulness of this reference in helping to frame questions regarding the visitor experience in Glacier Bay is relatively low. **Applicability: Low.**

Hollenhorst, S., E. I. Frank, et al. (1994). The Capacity to Be Alone: Wilderness Solitude and Growth of the Self in International Wilderness Allocation, Management, and Research. J. C. Hendee and V. G. Martin. Ft. Collins, CO, International Wilderness Leadership (WILD) Foundation**:** 234-239.

Visitor Experience. *Abstract: Wilderness is often justified by the exceptional opportunity it provides modern humans to experience solitude. Solitude is generally defined in the philosophical literature as the capacity to cope positively with time spent alone. While loneliness is one of the most powerful of human fears, optimal experience occurs when a person is able to control attention and find personal reward when alone, in the absence of external goals, stimulation, and feedback. To be alone but not lonely; to view isolation as an opportunity for personal growth and development, is the mark of self-realization and self-discovery.*

In this paper, we explore, through literature review and survey research, the meaning and structure of solitude as a benefit of the Wilderness experience. The findings suggest the capacity to realize positive benefit from wilderness solitude is hierarchical in structure; from physical renewal at the lower end to self-discovery and self-realization at the highest levels. This capacity for personal growth appears to be positively related to wilderness involvement and commitment. A weak or nonexistent relationship existed between the level of wilderness solitude benefit achieved and the physical/social characteristics of the setting. Paradoxically, although wilderness solitude was positively perceived and highly valued, people rarely go alone into wilderness. While a partial explanation can be found in concern for personal safety, evidence also suggests fear of loneliness, along with the overwhelming importance placed on developing intimate relationships at the expense of the need to be alone. Management implications will also be discussed.

Major relevant findings of this paper include conceptual distinction between solitude and privacy; aloneness as a necessary condition of solitude; and the hierarchical benefits of wilderness solitude extending from physical renewal to self-discovery and self-realization. Findings are based on a survey of wilderness visitors and literature review. High

applicability and usefulness to the issue of visitor experience in Glacier Bay is based on generalization of study findings regarding the nature of solitude and privacy in wilderness. **Applicability: High.**

Hornback, K. E. and P. F. J. Eagles (1999). Guidelines for Public Use Measurement and Reporting at Parks and Protected Areas. Gland, Switzerland Cambridge, UK, IUCN.

Measuring and Monitoring. *Excerpted from the Foreword: The World Commission on Protected Areas (WCPA) is a Commission of the World Conservation Union (IUCN). In April 1996 the WCPA established a task force to deal with strategic objectives of tourism and protected areas....Phase 1 was the development of definitions, approaches and standards on public use measurement and reporting for protected areas. The guidelines in this report are designed to work towards this end.*

Of particular interest to the visitor experience in Glacier Bay is Chapter 4 Visitor Studies, especially Sections 4.5 Studies on Satisfaction; 4.6 Studies of Crowding and Conflict; 4.7 Studies of Environmental Attitudes, Beliefs, Expectations, Perceptions; and 4.8 Studies of Public Values, Wants and Needs. These sections explain the purpose and application of each of these types of study. Survey design is discussed and examples are provided. **Applicability: High.**

Johnson, D. R. (1990). Glacier Bay National Park Tour Boat Passenger Visitor Survey 1989, National Park Service Cooperative Park Studies Unit. College of Forest Resources University of Washington**:** 174.

Measuring and Monitoring. This document reports the results of a Glacier Bay visitor survey conducted during the summer of 1989. Major relevant findings include data on park use and user profiles provided by respondents and information regarding visitor expectations, motivations, preferences, and satisfaction. The study was conducted under approved NPS protocols and is important because it provides baseline data for comparison with more contemporary information. The data includes responses regarding cruise ships in Glacier Bay. The study has direct applicability and high value in addressing the issue of visitor experience in Glacier Bay. **Applicability: High.**

Johnson, D. (2002). "Environmentally Sustainable Cruise Tourism: A Reality Check." Marine Policy **26**: 261-270.

Park Planning and Management. *Abstract: Cruise tourism continues to be a major international growth area. In terms of achieving sustainable tourism it is, therefore, a sub-sector within which socio-economic, cultural and environmental considerations need to be continually analyzed,*

addressed and monitored. The environmental impacts of cruise tourism are categorized in this paper and potential strategies that can be employed by both cruise line operators and cruise tourism destinations are explored. Secondary evidence of action by both parties suggests that the industry is taking a number of belated positive steps. However, decision-makers in cruise tourism destinations, particularly those outside North America, need to work closely with operators to facilitate both integrated waste management and intergenerational and intra-societal equity rather than merely accept the prospect of short-term economic gain.

The major relevant finding of this paper is its focus on cruise ship tourism and the environment. It represents one of a limited number of references to directly address this issue. It does not present any planning framework or system or specifically address the issue of visitor experience impacts and does not address park or wilderness management issues. Instead it describes environmental impacts and recommends attention to issues of social equity. Therefore, the applicability of this reference to the issue of visitor experience in Glacier Bay is relatively low. **Applicability: Low.**

Kakoyannis, C., B. Shindler, et al. (2001). Understanding the Social Acceptability of Natural Resource Decisionmaking Processes By Using a Knowledge Base Modeling Approach. Gen. Tech. Rep. Portland, OR, USDA Forest Service, Pacific Northwest Research Station**:** 40.

Park Planning and Management. *Abstract: Natural resource managers are being confronted with increasing conflict and litigation with those who find their management plans unacceptable. Compatible and sustainable management decisions necessitate that natural resource agencies generate plans that are not only biologically possible and economically feasible but also socially acceptable. Currently, however, we lack a framework to integrate socially acceptable judgments with plans. This research examines the ability of a knowledge base approach to assess the social acceptability of natural resource decisionmaking processes and to determine its suitability for use in forest management planning.*

We note four main caveats with using knowledge bases for evaluating social acceptability: (1) the importance of asking and answering the right question, (2) the ability of the knowledge base to become a "black box," (3) problems associated with using a numerical value to estimate a concept as complex as social acceptability, (4) and our incomplete understanding of the factors that influence social acceptability judgments. Acknowledging the caveats, however, can make the knowledge base model a useful tool in forest management planning. We determined that knowledge bases can account for various factors affecting social acceptability and can facilitate discussions about the compatibility and links among social, biological, and economic decision factors.

This report provides a useful review of the concept of social acceptability for use in designing meaningful research to address the issue of managing visitor experience in Glacier Bay National Park & Preserve. The major relevant finding of this report is to identify the limitations of the concept of social acceptability in managing the visitor experience in Glacier Bay. The concepts presented in the report could prove to be of limited (moderate) applicability to Glacier Bay visitor experience planning. **Applicability: Moderate.**

Kakoyannis, C. and G. H. Stankey (2002). Assessing and Evaluating Recreational Uses of Water Resources: Implications for an Integrated Management Framework. Gen. Tech. Rep. Portland, OR, USDA Forest Service Pacific Northwest Research Station**:** 59.

Park Planning and Management. *Abstract: To resolve conflicts over water, we need an understanding of human uses and values for water. In this study, we explore how water-based recreation affects and is affected by the water regime and water management and how key social trends might influence future water-based recreation. We found that although water is a critical component of many recreational experiences, our failure to understand current and anticipated water-based recreation use trends hampers our ability to effectively mange for recreation. Furthermore, we examined certain key drivers of social change, including population growth and migration, which will likely alter future recreation trends in the Pacific Northwest.*

We identified changes to the water resource, such as altered flow regimes, that have important consequences for the availability and quality of recreation opportunities. Although there are a variety of conflicts among recreationists and between recreation and other uses of water, we have a limited understanding of how to resolve them. Effective management will require examining the links between recreational opportunities and water management to minimize negative impacts to both recreation and the water regime.

The major relevant finding of this technical report is to address the issue of water recreation management and the need to integrate social pressures and use patterns into future management strategies. This has application to the visitor experience issue in Glacier Bay, however, the scope of the document is limited to freshwater resources and does not address the saltwater/cruise ship issues found in Glacier Bay. Therefore, its applicability to the Glacier Bay visitor experience is relatively low. **Applicability: Low.**

Kaplan, R. and S. Kaplan (1989). The Experience of Nature. Cambridge, New York, Port Chester, Melbourne, Sydney, Cambridge University Press.

> **Visitor Experience.** This book provides a scientific inquiry into the range of human experience of nature, from urban to wilderness. Environmental preference is intimately tied to underlying human needs and provides the context in which humans can thrive. A variety of variables must be addressed to understand the factors affecting perception and preference, including an individual's experience and culture.
>
> This book provides a conceptual framework for discussing the experience of nature in Glacier Bay National Park & Preserve, but no specific data or framework. **Applicability: Low.**

Klein, R. A. (2002). Cruise Ship Blues - The Underside of the Cruise Industry. Gabriola Island, Canada, New Society Publishers.

> **Visitor Experience.** The impacts of cruise ships in Glacier Bay are discussed in detail in this behind-the-scenes report on the cruise ship industry. Major relevant findings include a detailed accounting of the regulation of cruise ships in Glacier Bay including water quality violations, a humpback whale collision, court decisions and congressional action (pgs. 109-112). The author uses investigative reporting techniques, including researching the public record, traveling aboard cruise ships to Glacier Bay, and information supplied by cruise ship industry representatives to tell the story. This work has significant merit and high applicability in its synthesis of many disparate sources of information regarding cruise ship activity in Glacier Bay. Its usefulness is limited to the subjects it covers, primarily water quality and wildlife disturbance issues, and does not include examination of other aspects of the visitor experience in Glacier Bay. This reference has high value for use in addressing visitor experience issues in Glacier Bay. **Applicability: High.**

Kneeshaw, K., A. Watson, et al. (2004). Understanding Wilderness Visitor Experiences at Wrangell-St. Elias National Park and Preserve in the Alaska Regional Context. Wrangell-St. Elias National Park and Preserve Summer 2003 Visitor Study, Aldo Leopold Wilderness Research Institute USDA Forest Service Rocky Mountain Research Station**:** 47+appendices.

> **Measuring and Monitoring.** The objective of this research was to increase understanding of visitor expectations and received experiences at Wrangell St. Elias National Park & Preserve (WRST). Major relevant findings included visitors contrasting their experience in WRST to other backcountry trips in terms of trip preparation and planning, backcountry access, base camping, and the natural environment, primitive conditions, and remoteness of WRST. Most visitors compared and contrasted WRST

to their perception or experience of Denali National Park, although visitors also contrasted WRST to Gates of the Arctic, Katmai and Glacier Bay National Parks. This highly useful study enumerates the attributes thought to be significant to the wilderness visitor experience and provides an excellent reference to use in designing visitor experience research in Glacier Bay National Park & Preserve. **Applicability: High.**

Kravolec, M., A. Banks, et al. (2004). Distribution and Number of Backcountry Visitors in Glacier Bay National Park, 1996-2003.

Measuring and Monitoring. This presentation of backcountry visitor use survey data reports the trends of park use by private backcountry, commercially guided, and private vessel owners during a period of declining use. The surveys also collected visitor comments on a wide range of visitor experience issues. Major relevant findings include patterns of declining numbers of visitors. The surveys were conducted under approved NPS protocols and are important because it provides baseline park use data. The survey data has direct applicability and high value in addressing the issue of visitor experience in Glacier Bay. **Applicability: High.**

Lawson, S. R. and R. E. Manning (2002). "Tradeoffs Among Social, Resource, and Management Attributes of the Denali Wilderness Experience: A Contextual Approach to Normative Research." Leisure Sciences **24**: 297-312.

Park Planning and Management. *Abstract: Wilderness experiences are thought to be comprised of three primary dimensions, including social resource, and management conditions. Decisions about how to manage wilderness recreation in Denali National Park and Preserve involve potential trade-offs among these conditions. This study extends the normative approach to wilderness research by developing and applying a decision-making model that considers social, resource, and managerial attributes of the wilderness experience within a more holistic context. Specifically, stated choice analysis is used to evaluate the choices overnight wilderness visitors make when faced with hypothetical tradeoffs among the conditions of social, resource, and management attributes of the Denali wilderness. Study findings offer normative, but contextually informed empirical guidance in formulating indicators and standards of quality for the wilderness experience.*

The major relevant finding of this study is the usefulness of choice analysis in addressing complex and controversial trade-offs among social, resource and management attributes when managing wilderness. By extending the application of normative research to assist difficult management issues, this study has potential to provide assistance in the

issue of visitor experience in Glacier Bay and therefore us of moderate applicability. **Applicability: Moderate.**

Lime, D. W. (1990). Managing America's Enduring Wilderness Resource Proceedings of the Conference Minneapolis, Minnesota September 11-17, 1989, Minneapolis, MN, St. Paul, MN Minnesota Extension Service U of M.

Park Planning and Management. *Abstract: Summarizes some of the activities and accomplishments of a major wilderness management conference held in Minnesota in 1989 to commemorate the 25th anniversary of the National Wilderness Preservation System and to address three themes pertinent to wilderness management as we move into the system's second half century: (1) managing resources and people within wilderness, (2) managing lands adjacent to wilderness, and (3) linking tourism, wilderness, and economic development.*

This very useful reference presents many papers with application to the issue of visitor experience in Glacier Bay National Park & Preserve. Several of the most pertinent are individually annotated. The major relevant findings of this conference include papers on managing resources and people within wilderness, and monitoring social conditions in wilderness. Experts in the field have presented their work and the reference is an authoritative, if somewhat dated, document. Because of the wide range of wilderness management issues presented, it is a highly valuable reference with high applicability to issues of visitor experience in Glacier Bay. **Applicability: High.**

Lindberg, K., S. F. McCool, et al. (1996). Rethinking Carrying Capacity.

Measuring and Monitoring. In this reference the authors propose that carrying capacity is not a useful tool to apply to questions of tourism management. The three reasons for this limitation are 1) carrying capacity definitions often provide little guidance for practical implementation (i.e. what is visitor satisfaction?) 2) although carrying capacity is perceived as a scientific, objective concept its criteria are inherently subjective and 3) carrying capacity typically focuses on use levels or number of visitors (a social or experiential condition) but management objectives typically relate to conditions. There is abundant literature that discounts the relationship between use levels and impacts. The authors conclude that use of the carrying capacity concept should be abandoned in favor of alternative, more appropriate frameworks such as the Limits of Acceptable Change (LAC), Visitor Impact Management (VIM) and Visitor Experience Resource Protection (VERP).

This recommendation would suggest avoiding use of the concept of carrying capacity when measuring and monitoring visitor experience in Glacier Bay National Park & Preserve. **Applicability: High.**

Littlejohn, M. (2000). Glacier Bay National Park Bartlett Cove Visitor Study Summer 1999, Visitor Services Project. Cooperative Park Studies Unit, University of Idaho**:** 115.

Measuring and Monitoring. From the Report Summary: *This report describes the results of a visitor study at Bartlett Cove in Glacier Bay National Park from July 23 - August 1, 1999. A total of 666 questionnaires were distributed to Bartlett Cove visitors. Visitors returned 545 questionnaires for an 81.7% response rate. This report profiles Bartlett Cove visitors at Glacier Bay National Park, including both land-based activities and tour boats that entered Bartlett Cove. A separate appendix contains visitors' comments about their visit. This report and the appendix include summaries of those comments.*

The major relevant finding of this document is its presentation of visitor use data for Glacier Bay National Park & Preserve. Questionnaires were distributed to Bartlett Cove visitors. An analysis of responses and visitor comments are presented. The study presents some of the best and most recent visitor use data for GBNP&P and has direct applicability in addressing visitor experience issues in the park. **Applicability: High.**

Mace, B. L., P. A. Bell, et al. (2004). "Visibility and Natural Quiet in National Parks and Wilderness Areas: Psychological Considerations." Environment and Behavior **36**(1): 5-31.

Visitor Experience. *Abstract: For over a century, authorities have recognized cultural and psychological benefits of preserving national parks and wilderness areas. Yet, with increases in visitation and mechanized travel, air and noise pollution are intruding more and more into preserved natural areas. Psychological research shows that 1) humans can detect very low levels of these pollutants in natural and laboratory settings, 2) air and noise pollution detract from the enjoyment of the visitor experience, and 3) people place a high value on naturally quiet, pollution-free settings. This article discusses how psychological research is essential for a more complete understanding of the value and the influence of both visibility and quiet surroundings with a focus on applied, field-based research in national parks and wilderness areas. The article concludes with recommendations for future directions in research in these areas and argues that implications of psychological research results should be addressed in the natural resource policy-making process.*

The major relevant finding of this article is that stressors affecting the quality of wilderness visitor experience include not only ambient effects but also factors of predictability, control, and source attribution. The paper reviews literature in the field of environmental psychology and provides a useful discussion of this aspect of visitor experience. The discussion can be generalized for use in Glacier Bay to provide high applicability and usefulness in designing visitor experience research for Glacier Bay. **Applicability: High.**

Manning, R. E. (1986). Studies in Outdoor Recreation - Search and Research for Satisfaction. Corvallis, OR, Oregon State University Press.

Measuring and Monitoring. This book serves as a review and synthesis of scientific literature regarding the social aspects of outdoor recreation. It discusses the concepts of carrying capacity as an organizational framework; density; crowding; and satisfaction. One chapter is devoted to explaining the Recreation Opportunity Spectrum (ROS).

The ten major principles presented in this reference are as follows:

A. Outdoor recreation management should be considered within a three-fold framework of concerns: 1) the natural environment, 2) the social environment, and 3) the management environment.
B. There is great diversity in public tastes for outdoor recreation.
C. Diversity is needed in outdoor recreation opportunities.
D. Explicit objectives are needed to guide management of outdoor recreation opportunities.
E. Satisfaction of visitors to outdoor recreation areas is a multifaceted concept.
F. Outdoor recreation is more appropriately defined in terms of fulfilling motivations than participation in activities.
G. Quality in outdoor recreation is the degree to which opportunities satisfy the motivations for which they are designed.
H. Differences in the perceptions of outdoor recreation visitors and managers require a concerted effort to obtain systematic and objective information about and from visitors.
I. Outdoor recreation opportunities should be managed for relatively homogeneous groups of visitors.
J. A variety of practices is available for managing outdoor recreation.

This reference is a useful guide in the development of visitor experience research and visitor management plans for Glacier Bay National Park & Preserve. **Applicability: High.**

Manning, R. E., D. W. Lime, et al. (1995). "The Visitor Experience and Resource Protection (VERP) Process: The Application of Carrying Capacity to Arches National Park." The George Wright Forum **12**(3): 41-55.

> **Park Planning and Management.** Because the quality of visitor experience in national parks is to be maintained at a high level, application of the Visitor Experience and Resource Protection (VERP) process was used to develop visitor use management prescriptions for Arches National Park. These prescriptions were then applied in the development of a management plan designed to identify and manage carrying capacity in the national park. This paper may have application to Glacier Bay National Park & Preserve if the VERP process is to be used in addressing visitor experience issues. **Applicability: High.**

Manning, R., D. Johnson, et al. (1996). "Norm Congruence Among Tour Boat Passengers to Glacier Bay National Park." Leisure Sciences **18**: 125-141.

> **Measuring and Monitoring.** *Abstract: Personal and social norms of visitors are receiving increased attention as a means of setting standards of quality in parks and recreation areas. However, if visitors' evaluations and behavior are not congruent with norm-based standards, then this approach may lack validity. This study tests norm congruence among tour boat passengers to Glacier Bay National Park. A sample of tour boat passengers was surveyed to determine (a) personal norms for the number of watercraft and aircraft seen, (b) number of watercraft and aircraft seen, and (c) the effect of watercraft and aircraft seen on enjoyment. Findings reveal the extent to which evaluations of seeing watercraft and aircraft are congruent with data on personal norms. Several theoretical and methodological issues that help interpret study findings are discussed.*
>
> Major relevant findings include demonstration of congruency of personal norms and norm-based standards for tour boat passenger sightings of watercraft and aircraft in Glacier Bay. In addition, data collected is directly applicable to questions of visitor experience in Glacier Bay. However, data does not specifically address the issue of effects of cruise ship sightings on tour boat passengers. The study analyzed responses to a questionnaire distributed to tour boat passengers in Glacier Bay and provides some of the only survey data on Glacier Bay visitor experience. It was conducted to the highest scientific standards and has direct applicability to the issue of visitor experience in Glacier Bay. Its usefulness is limited only because the study does not directly address the question of visitor perceptions of cruise ships in Glacier Bay. **Applicability: High.**

Manning, R. E., D. W. Lime, et al. (1996). "Social Carrying Capacity of Natural Areas: Theory and Application in the U.S. National Parks." Natural Areas Journal **16**(2): 118-127.

> **Park Planning and Management.** *Abstract: Concern over increasing visitor use of natural areas such as national parks has focused attention on the concept of carrying capacity. Research and management experience suggests that carrying capacity has both biological and social components. Moreover, carrying capacity might be addressed most effectively through identification of indicators and standards of quality. Monitoring of indicator variables would ensure that standards of quality are not violated. Using this approach, the U.S. National Park Service recently designed a carrying capacity-related planning framework called Visitor Experience and Resource Protection (VERP). This planning framework was pilot-tested at Arches National Park through a program of social science research. Based on this research, a series of indicators and standards of quality were identified, a long-term monitoring program is being implemented, and management actions are being undertaken. The VERP process is now being refined and may serve as a model for the rest of the U.S. National Park System and related natural areas.*
>
> If the VERP process is used to address visitor management in Glacier Bay National Park & Preserve, this article can provide useful insights into its application. **Applicability: Moderate.**

Manning, R. E., W. A. Valliere, et al. (1999). "Crowding Norms: Alternative Measurement Approaches." Leisure Sciences **21**(2).

> **Measuring and Monitoring.** *Abstract: Research on crowding-related standards of quality increasingly has focused on personal and social norms. Several norm-measurement approaches have been developed. This study compares and evaluates three issues related to alternative norm measurement approaches: numerical versus visual approach, long versus short question format, and evaluative dimension. Study data are drawn from a multiphase program of research on crowding on the carriage roads of Acadia National Park, Maine. Differences in crowding norms developed from alternative measurement approaches are described and discussed. Study findings suggest that commonly used norm-measurement approaches may lead to crowding-related standards of quality that are overly conservative.*
>
> The major relevant finding of this paper is focused on the limitations of crowding norm measurements in developing recreation use restrictions. The study uses a comparative analysis and concludes that each measurement approach has advantages and disadvantages. The study

and its findings are limited in scope. They have moderate usefulness and potential applicability for Glacier Bay.

If crowding-related norms are developed for visitor experience in Glacier Bay National Park & Preserve, this reference can provide guidance in the collection of crowding data. **Applicability: Moderate.**

Manning, R. E. and W. A. Valliere (2001). "Coping in Outdoor Recreation: Causes and Consequences of Crowding and Conflict Among Community Residents." Journal of Leisure Research **33**(4): 410-426.

Measuring and Monitoring. *Abstract: Displacement, product shift, and rationalization are coping mechanisms that can be adopted in response to crowding and conflict in outdoor recreation. Using survey methods, this study found relatively high levels of adoption of coping mechanisms by residents of communities in and around Acadia National Park, Maine in response to perceived increases in 1) overall recreation use levels, 2) selected recreation activities and 3) selected problem behaviors. While only 7.4% of respondents reported that they no longer use the carriage roads because of the changes in use that have occurred, nearly all respondents (94%) reported adopting one or more behavioral or cognitive coping mechanisms. Study findings suggest that coping may be pervasive in outdoor recreation, that coping includes behavioral and cognitive coping mechanisms, and that coping is related to perceived changes in both the amount and type of outdoor recreation. High levels of coping as found in this study may be stressful at the individual level, may lead to diminished diversity of outdoor recreation opportunities at the societal level, and suggests that overall "satisfaction" may be a superficial and even misleading measure of quality in outdoor recreation.*

These findings have direct implications for the issue of visitor experience in Glacier Bay National Park & Preserve and indicate several avenues of inquiry when investigating impacts from increased visitor activity. **Applicability: High.**

Manning, R. E., S. Lawson, et al. (2002). "Methodological Issues in Measuring Crowding-Related Norms in Outdoor Recreation." Leisure Sciences **24**(3-4): 339-348.

Measuring and Monitoring. *Abstract: Based on theoretical and methodological similarities between research on recreation-related norms and contingent valuation, three methodological issues - question format, starting point bias, and information bias - are explored as they apply to measuring crowding-related norms of visitors to two national parks. Few statistically or substantively significant differences in crowding-related norms were found to be associated with these methodological issues.*

Study findings suggest that measures of crowding-related norms may be relatively "robust" and this may add weight to the "validity" of the theory and methods associated with crowding-related norms in outdoor recreation.

This paper is authored by an expert in the field. Study findings have moderate usefulness and potential applicability to Glacier Bay. If crowding-related norms are developed for visitor experience in Glacier Bay National Park & Preserve, this reference can provide guidance in the collection of crowding data. ***Applicability: Moderate.***

Manning, R. E. (N.D.). Social Carrying Capacity in the National Parks**:** 72.

Park Planning and Management. From the Executive Summary: *Rising demand for public access to the national parks has raised concern over the quality of the visitor experience. How many visits can the national parks accommodate before the quality of the visitor experience declines to an unacceptable degree? To help answer this question, the concept of social carrying capacity has been developed. This report explores the theory and application of social carrying capacity to the national parks.... the National Park Service should enhance its commitment to visitor-oriented research. Social carrying capacity determinations must incorporate objective data from national park visitors. In particular, visitor-oriented research should be expanded beyond its traditional emphasis on backcountry and related areas to a diversity of park settings - front country sites, historical and cultural areas, recreation areas, urban parks - and should explore social norms among park visitors as a means of formulating management standards.*

This paper offers a discussion about the study of visitor experience in national parks from one of the experts in the field and can be useful in addressing visitor experience in Glacier Bay National Park & Preserve. **Applicability: High.**

Martin, S. R. (1989). A Framework for Monitoring Experiential Conditions in Wilderness. Managing America's Enduring Wilderness Resource, Minneapolis, MN, Minnesota Extension Service U or M.

Measuring and Monitoring. *Abstract: Monitoring social or experiential conditions in wilderness is necessary to ensure quality visitor experiences. Although some progress has been made in monitoring resource conditions such as campsite impacts, monitoring the quality of visitor experiences has lagged behind. This paper outlines a step-by-step process to help managers develop an experiential monitoring program. Discussion of the kinds of indicators to monitor is included, as well as some advantages and*

disadvantages of several methods. Issues that should be addressed are also identified and discussed.

The major relevant finding of this paper is its focus on and discussion of visitor experience issues. Rather than recommend a specific monitoring framework or system, the author advocates identifying what indicators will be monitored and ensure they represent all of the components of the visitor experience. He advocates monitoring experiential conditions as a way of ensuring the quality of the visitor experience is maintained. The paper has direct (high) applicability to the issue of visitor experience management in GBNP&P. **Applicability: High.**

McCool, S. F. (1996). Limits of Acceptable Change: A Framework for Managing National Protected Areas: Experiences from the United States. A Paper Presented at Workshop on Impact Management in Marine Parks. Kuala Lumpur, Malaysia, Maritime Institute of Malaysia**:** 15.

Park Planning and Management. *Abstract: The Limits of Acceptable Change (LAC) planning system was developed in response to growing recognition in the U.S. that attempts to define and implement recreational carrying capacities for national park and wilderness protected areas were both excessively reductionistic and failing. The carrying capacity concept itself, while useful in a generic way to encourage discussion about visitor impacts, was based on biological models of the capability of resources to sustain a given number of animals over a period of time on a particular range or pasture. Such models did not transfer well into ecosystems being managed for human benefits based primarily on recreational experiences that were not themselves well understood. LAC was based on the recognition that (1) specific objectives were needed to identify what it was that management was to protect, (2) change is always present in nature-dominated systems, (3) any recreational use leads to some change, (4) management is therefore confronted with the question of how much change is acceptable, and (5) monitoring of the outcomes of management is needed to determine if actions were effective. In the U.S., LAS was first implemented in designated Wilderness managed by the USDA Forest Service. Since that time, additional work has been conducted in other areas, such as national parks using a derivative system termed the Visitor Experience and Resource Protection planning process. It has also been tested as a system for management of tourism development.*

The major relevant finding of this paper is the discussion of the application of the LAC framework in the United States. It is authored by an expert in the field and represents a wealth of experience on the subject. It has high applicability to the Glacier Bay visitor experience issue if the LAC planning framework is used. **Applicability: High.**

McCool, S. F., D. N. Cole, et al. (1997). Proceedings - Limits of Acceptable Change and Related Planning Processes: Progress and Future Directions; 1997 May 20-22; Missoula Montana. Gen. Tech. Report. Ogden, UT, USDA Forest Service, Rocky Mountain Research Station**:** 84.

Park Planning and Management. From the Research Summary: *This proceedings resulted from a workshop on Limits of Acceptable Change (LAC) and related planning processes. Workshop goals were to assess progress in applications of LAC and to work toward more successful applications in the future. Particular attention was given to concepts and terminology requiring clarification and to procedural revisions. Although initially developed to address the issue of recreation use in wilderness, the LAC process can clearly be used outside wilderness and to address issues other than recreation. Considerable attention was devoted to identifying the range of situations in which LAC can be usefully applied.*

To archive experience with these processes, the successes and failures with LAC applications were described. Attendees identified the means of addressing weaknesses and discussed barriers to effective implementation. Many of these are institutional in nature and will be difficult to change. Finally, workshop attendees felt strongly that certain innovations within the LAC process could make substantial contributions to improved planning within the Federal land management agencies.

Following an introductory review of how and why the workshop was held, the proceedings contains three sections. The first section is a compilation of the papers written by workshop attendees. The second section consists of three synthesis papers written by workshop organizers, David Cole and Steve McCool. These papers attempt to describe (1) recommended conceptual and terminology clarifications and modification to the LAC process, (2) the range of situations to which LAC and be usefully applied, and (3) lessons learned from 15 years of LAC applications. The third section is an annotated bibliography of LAC and LAC-related publications.

The major relevant findings of the proceedings of this conference include case study applications of LAC; discussions of the limitations of the LAC framework; and an exploration of LAC applications outside of wilderness. The reference gathers the work of numerous experts in the development and application of LAC and represents an authoritative work on the subject. It has direct (high) applicability to the issue of addressing visitor experience in Glacier Bay if a LAC planning framework is chosen. **Applicability: High.**

McCool, S. F., D. N. Cole, et al. (2000). Volume 2 Wilderness within the Context of Larger Systems. Wilderness Science in a Time of Change Conference, Missoula, MT, USDA Forest Service, Rocky Mountain Research Station.

> **Park Planning and Management.** *Abstract: Thirty-eight papers related to the theme of wilderness in the context of larger systems are included. Three overview papers synthesize existing knowledge and research about wilderness economics, relationships between wilderness and surrounding social communities, and relationships between wilderness and surrounding ecological communities and processes. Other papers deal with wilderness meanings and debates; wilderness within larger ecosystems; and social, economic, and policy issues.*
>
> The major relevant findings of these conference proceedings are papers discussing the meaning of wilderness and debates over how and for what/whom wilderness should be managed. This collection of papers by experts is useful in framing the questions which need to be asked about the management of visitor experience in Glacier Bay and therefore has high applicability. **Applicability: High.**

McCool, S. F. (2001). Limiting Recreational Use in Wilderness: Research Issues and Management Challenges in Appraising Their Effectiveness, USDA Forest Service.

> **Measuring and Monitoring.** *Abstract: Limits on the overall number of recreationists permitted to enter or visit wilderness, national park backcountry or whitewater rivers have been formally established for about 30 years. Such limits have usually been established to protect biophysical or social conditions from unacceptable impacts in the face of rapidly rising amounts of visitation. Use limits are one of a number of tools available to managers, but represent a particularly intrusive and controversial one. Use limit policies may have significant negative displacement effects, are implemented within a regional context - even if not recognized in the decision - and must meet the criteria of effectiveness, efficacy, and efficiency in order to be useful in managing impacts. Unfortunately, evaluations of use limit policies using these criteria do not exist within the literature. The paper suggests that evaluations encompass four major domains, consider effects within a regional context, and research move from one-shot case study experimental designs to those that are more conducive to better understanding of the consequences of use limit policies.*
>
> The major relevant finding of this paper is the recommendation that recreational use limits should be considered in a regional context. The paper does not recommend specific research methodologies for investigating recreational use limits. Use of the regional perspective could

have some limited (low) application to the issue of cruise ship limitations in Glacier Bay since cruise ship/visitor experience issues do extend beyond the boundaries of GBNP&P. **Applicability: Low.**

McCool, S. F. (2002). Principles and Concepts for Managing Visitor Impacts in Protected Areas. Conference on Carrying Capacity and Visitor Management in Protected Areas, Athens, Greece.

Park Planning and Management. Excerpted from Introduction: *Protected area managers have three responsibilities that direct the stewardship of the special places under their care. First, managers protect the attributes, uses and values that were identified in the enabling legislation or decree that established the protected area. Second, managers provide for the highest quality of opportunity for recreational, historical, educational and spiritual uses permitted or authorized in the area. Finally, managers interact with communities adjacent to or within the protected area to accommodate their interests, including those that are political, economic and cultural in character...."*

The major relevant findings of this paper are three guiding propositions, eleven principles, and seven criteria to guide the management/planning decision-making framework for visitor impacts in protected areas. It has high applicability to the visitor experience issue in Glacier Bay.

The paper concludes "*The principles discussed here provide a foundation for applying a systematic decision-making process, that when coupled with adequate and appropriate public involvement can lead to successful visitor management in protected areas."* **Applicability: High.**

McCool, S. F. (2002). Tourism in Protected Areas: Continuing Challenges and Emerging Issues for Sustaining Visitor Experiences. Celebrating Mountains, Jindabyne, NSW Australia.

Park Planning and Management. The paper outlines continuing challenges as follows: *"There are three significant challenges that confront those for whom providing high quality recreation and tourism opportunities is important. First, mapping and measuring the experiences visitors' desire persists as a major challenge, not only for researchers, but also for the park managers mandated to provide opportunities and businesses seeking to find a profitable market. Second, linking these desired experiences to the attributes that are needed to provide for them remains problematic. And, third, the relationship between the natural environment, which serves as the foundation for these desired experiences and the tourism industry that often exploits them is often poorly understood, yet fundamental to sustainability.*

Major relevant findings of this paper are stated in the Conclusion as follows: *Sustaining visitor experiences remains one of the most challenging tasks of protected area managers for they must integrate sociology, psychology, political science and biology into a set of decisions that can only provide opportunity, not determine quality. Visitor experience decisions remain challenging because they also require integration of science and planning to develop opportunities that are difficult to tangibly describe. In addition, because managers of protected areas are generally rewarded for the stewardship they provide their area, there are distinct possibilities that gaps in the spectrum of opportunities may occur, opportunities may be homogenized, and duplication may occur.*

The science of managing visitor opportunities within a systems context is not particularly well developed (McCool and Cole 2001). The science of identifying the experiences visitors seek has a strong conceptual foundation and is evolving to be more inclusive of different approaches and paradigms. We understand how to differentiate different types of experiences, we understand somewhat less how to manage to provide opportunities for people to experience these opportunities, we understand least, and are uncomfortable most with, how to make decisions about for whom - in the sense of experiences - a park should be managed. This paper speaks directly to the visitor experience issue in Glacier Bay and has high applicability. **Applicability: High.**

Merigliano, L. L. (1990). Indicators to Monitor the Wilderness Recreation Experience. Managing America's Enduring Wilderness Resource, Minneapolis, MN, Minnesota Extension Service U of M.

Measuring and Monitoring. *Abstract: Mere designation of an area as Wilderness does not insure that desired wilderness conditions will be achieved. Managers seeking to document how much change is occurring in wilderness conditions have increasingly looked to the use of indicators, which are defined as specific elements of the wilderness setting that change in response to human activities. Physical, social, and managerial setting attributes can be used to indicate the quality of the wilderness recreation experience. However, even the most ambitious monitoring program will only be able to include a limited number of indicators. Nine criteria, which reflect important characteristics indicators should possess, are presented in this paper to help guide indicator selection. Eighteen potential indicators are identified which could be used to reflect the ability of the wilderness area to provide visitors with the opportunity to feel close to nature, see unmodified natural environments, and experience solitude, intragroup intimacy, challenge, health, and freedom of choice. Managers are encouraged to select indicators tailored to their particular area by first*

interviewing visitors to determine which specific setting attributes really enhance or detract from the experience.

The major relevant finding of this paper is the discussion of indicators to use for monitoring visitor experience. It has direct (high) application to the issue of developing monitoring indicators for the visitor experience in GBNP&P. **Applicability: High.**

Muir, J. (1915). Travels in Alaska. Boston and New York, Houghton Mifflin Company.

Visitor Experience. *From the Preface: In 1879 John Muir went to Alaska for the first time. Its stupendous living glaciers aroused his unbounded interest, for they enabled him to verify his theories of glacial action. Again and again he returned to this continental laboratory of landscapes.* Chapter X "The Discovery of Glacier Bay" narrates John Muir's first visit to Glacier Bay. Chapter XVII "In Camp at Glacier Bay" details his return visit.

This reference presents an early Glacier Bay visitor experience narrative. John Muir's writings about Glacier Bay helped to highlight its unique values and were later used in support of its protection by executive and congressional action. His work is in first person narrative and he reports on information acquired through personal exploration and reconnaissance. This writing is considered of the highest quality and is of direct application to Glacier Bay. His work is limited to his own personal observation during his two visits to the area. **Applicability: High.**

Nash, R. (1967). Wilderness and the American Mind. New Haven, Yale University Press.

Visitor Experience. This book is a seminal reference on the subject of wilderness and its meaning in the American landscape. It tracks the changing conception of wilderness in American history from Old world perspective through romantic construction to modern wilderness management.

The book provides a good general foundation from which to understand the cultural significance of Glacier Bay National Park & Preserve. **Applicability: Moderate.**

Nemeth, D. (2005). Glacier Bay National Park & Preserve Visitor Use Statistics 1966-2005.

Measuring and Monitoring. This summary of visitor use statistics was prepared primarily from Park Monthly Public Use Reports. It provides useful information on current use patterns as well as trends over the past

forty years. It has direct usefulness and high applicability in addressing visitor experience issues in Glacier Bay. **Applicability: High.**

O'Reilly, A. M. (1986). Tourism Carrying Capacity - Concept and Issues. Tourism Management**:** 254-258.

Measuring and Monitoring. *Abstract: This article examines the concept of carrying capacity, the calculation and control of which has not been taken seriously by developers, whether public or private, especially in developing countries. This has resulted in many cases in overcapacity within the areas developed for tourism, causing the destruction or near-destruction of historical landmarks and even the natural environment. Thus it is necessary for the concept of tourism carrying capacity to be included in the planning for tourism as initiated by governments and other developers, in spite of difficulties in measurement.*

The discussion of the limits of using the carrying capacity concept for managing tourism may be useful in addressing the question of visitor experience in Glacier Bay National Park & Preserve. **Applicability: Low.**

Roggenbuck, J. W., D. R. Williams, et al. (1993). "Defining Acceptable Conditions in Wilderness." Environmental Management **17**(2): 187-197.

Measuring and Monitoring. *Abstract: The limits of acceptable change (LAC) planning framework recognizes that forest managers must decide what indicators of wilderness conditions best represent resource naturalness and high-quality visitor experiences and how much change from the pristine is acceptable for each indicator. Visitor opinions on the aspects of the wilderness that have great impact on their experience can provide valuable input to selection of indicators. Cohutta, Georgia; Caney Creek, Arkansas; Upland Island, Texas; and Rattlesnake, Montana; wilderness visitors have high shared agreement that littering and damage to trees in campsites, noise, and seeing wildlife are very important influences on wilderness experiences. Camping within sight or sound of other people influences experience quality more than do encounters on the trails. Visitors' standards of acceptable conditions within wilderness vary considerably, suggesting a potential need to manage different zones within wilderness for different clientele groups and experiences. Standards across wildernesses, however, are remarkably similar.*

The major relevant finding of this article is the indication that acceptable conditions may vary among park user groups. This has direct (high) applicability to research design and management of the Glacier Bay visitor experience. **Applicability: High.**

Salvi, W. C. and D. Johnson (1985). Glacier Bay Backcountry User Study 1984: Statistical Abstract, National Park Service Cooperative Park Studies Unit. College of Forest Resources, University of Washington.

> **Measuring and Monitoring.** The primary purpose of this study was to provide information necessary to the development of a Backcountry Management Plan at Glacier Bay National Park. Major relevant findings include park use and user profiles provided by respondents and the comments provided by visitors. The study was conducted under approved NPS protocols and is important because it provides baseline data for comparison with more contemporary information. Among the many questions asked were several addressing cruise ships in Glacier Bay. The study has direct applicability and high value in addressing the issue of visitor experience in Glacier Bay. **Applicability: High.**

Schreyer, R. and J. W. Roggenbuck (1978). "The Influence of Experience Expectations on Crowding Perceptions and Social-Psychological Carrying Capacities." Leisure Sciences **1**(4): 373-394.

> **Visitor Experience.** *Abstract: Carrying capacities for recreation have been difficult to determine because of the tendency to consider perception of crowding as a generalized human value. Rather, such perceptions are a function of the differing expectations people may have for given recreational experiences. A study of whitewater river recreationists in Dinosaur National Monument showed that persons who score more highly in certain experience expectations are more sensitive to crowding, that different expectations show varying sensitivities to crowding and that various user groups differ significantly in the rated importance of these expectations. A wilderness attitude scale was also employed. Persons differing in their wilderness scores also differed significantly in the rated importance of the various experience expectations, as well as in their sensitivity to crowding. Implications for the management of recreational resources are discussed.*
>
> The major relevant finding of this paper is to identify the importance of visitor expectations in shaping and determining visitor experience. The author used a questionnaire survey of river recreationists at Dinosaur National Monument to investigate experience expectations. The issue of experience expectations has moderate usefulness (applicability) to determining visitor experience impacts in Glacier Bay. **Applicability: Moderate.**

Shafer, S. C. and W. E. Hammitt (1995). "Congruency Among Experience Dimensions, Condition Indicators and Coping Behaviors in Wilderness." Leisure Sciences.

Measuring and Monitoring. *Abstract: Understanding the way that policy translates into experiences, perceptions, and behaviors is important to managing recreation in wilderness. The limits of acceptable change (LAC) planning system was used to structure a relationship between three constructs: experience dimensions (goals), conditions of concern (condition indicators), and coping behaviors (actions) in wilderness recreation. The Wilderness Act of 1964 served as a conceptual basis, providing five descriptors: natural, solitude, primitive, unconfined, and remote; these were used to develop experience, condition, and behavior measures. Recreationists from two wildernesses in the southeastern United States were sampled and asked to participate in a mail survey. Results indicated that wilderness experience dimensions existed that reflected the five descriptors, and that these dimensions were congruent with the constructs representing perceived conditions and coping behaviors. Natural and solitude aspects of the recreational experience were most significant in the relationships among constructs. Results suggest that recreationists use behaviors to control and manage conditions, and thus their experience, in wilderness.*

The major relevant finding of this paper is the indication of visitor experience being controlled and modified by visitor behaviors. This suggests the interactive nature of visitor experience and the necessity to factor in visitor coping behaviors when addressing visitor management issues. These findings have high applicability to the issue of cruise ships and visitor experience in Glacier Bay. **Applicability: High.**

Shafer, C. S. and G. J. Inglis (2000). "Influence of Social, Biophysical, and Managerial Conditions on Tourism Experiences with the Great Barrier Reef World Heritage Area." Environmental Management **26**(1): 73-87.

Park Planning and Management. *Abstract: Managing protected areas involves balancing the enjoyment of visitors with the protection of a variety of cultural and biophysical resources. Tourism pressures in the Great Barrier Reef World Heritage Area (GBRWHA) are creating concerns about how to strike this balance in a marine environment. Terrestrial-based research has led to conceptual planning and management frameworks that address issues of human use and resource protection. The limits of acceptable change (LAC) framework was used as a conceptual basis for a study of snorkeling at reef sites in the GBRWHA. The intent was to determine if different settings existed among tourism operators traveling to the reef and, if so. to identify specific conditions relating to those settings. Snorkelers (N=1475) traveling with tourism operations of different sizes who traveled to different sites completed surveys. Results indicated that snorkelers who traveled with larger operations (more people and infrastructure) differed from those traveling with smaller operations (few people and little on-site infrastructure) on benefits received and in the way*

that specific conditions influenced their enjoyment. Benefits related to nature, escape, and family helped to define reef experiences. Conditions related to coral, fish, and operator staff had a positive influence on the enjoyment of most visitors but, number of people on the trip and site infrastructure may have the greatest potential as setting indicators. Data support the potential usefulness of visitor input in applying the LAC concept to a marine environment where tourism and recreational uses are rapidly changing.

The major relevant finding of this paper is a case study application of LAC planning framework in a marine park setting. Although the study was conducted in a marine setting, it focused on reef snorkelers and therefore has only limited (low) applicability to Glacier Bay management issues regarding cruise ship and visitor experience. **Applicability: Low.**

Shelby, B. and T. A. Heberlein (1986). Carrying Capacity in Recreation Settings. Corvallis, OR, Oregon State University Press.

Measuring and Monitoring. This widely referenced book explains the conceptual framework for carrying capacity and presents research design examples used to make carrying capacity judgments. Carrying capacity is defined as the level of use beyond which impacts exceed acceptable levels specified by evaluative standards. This book is a useful reference for researchers and resource managers alike and can be referred to when applying the carrying capacity concept to management issues in Glacier Bay National Park & Preserve. **Applicability: High.**

Shelby, B., J. J. Vaske, et al. (1989). "Comparative Analysis of Crowding in Multiple Locations: Results from Fifteen Years of Research." Leisure Sciences **11**: 269-291.

Measuring and Monitoring. *Abstract: Crowding is one of the most frequently studied phenomena in the outdoor recreation literature, but almost all the research focuses on single populations or settings and individual-level analysis. The present study uses comparative analysis of aggregate data to explore questions that single studies cannot answer. Data come from more than 17,000 individuals in 35 studies of 59 different settings or activities located throughout the northeast, midwest, and northwest United States and New Zealand. All the studies used the same single-item measure to assess visitor judgments of crowding. Dividing the nine-point response scale to reflect the percentage of respondents reporting some degree of crowding produced a single crowding rating for each setting. Crowding scores ranged from 12 to 100%, with a mean of 57% (standard deviation, 22%). The analyses suggest that crowding varies by time, resource availability, accessibility and convenience, and management strategy. Factors that did not affect crowding included the*

region of the United States in which the study was done, the type of activity studied (consumptive or nonconsumptive), and the methodology used to collect the data (on-site survey or mailed questionnaire). To extend earlier work we also reassessed efforts to use aggregate crowding ratings to identify areas with potential carrying capacity problems. On the basis of the large number of studies done and our experience with the settings in which they were conducted, we developed five classifications ranging from high use-high impacts areas, where management or natural factors actively limit use to provide low-density experiences. Because of the simplicity of this scale and its usefulness for comparative analysis, we urge investigators to use it in other studies so that the database can be expanded.

The major relevant finding of this paper is the analysis of fifteen years of research addressing issues of crowding, carrying capacity and limits of acceptable change. This analysis may have application and high applicability in designing and interpreting visitor experience data for Glacier Bay National Park & Preserve. **Applicability: High.**

Shelby, B. and J. Vaske (1991). "Using Normative Data to Develop Evaluative Standards for Resource Management: A Comment on Three Papers." Journal of Leisure Research **23**: 173-187.

Measuring and Monitoring. This paper describes the usefulness of normative data for developing standards and reviews three papers which address the use of norms. It concludes that the usefulness of the normative approach lies in the ability to characterize group agreement regarding impact levels and appropriate use conditions. This data provides the evaluative information used to develop management standards. According to the authors, normative approaches have potential to put evaluative standards on an empirical basis. **Applicability: Moderate.**

Shelby, B., G. H. Stankey, et al. (1992). Defining Wilderness Quality: The Role of Standards in Wilderness Management - A Workshop Proceedings; 1990 April 10-11 Fort Collins, CO. Portland, OR, USDA Forest Service, Pacific Northwest Research Station**:** 114.

Park Planning and Management. *Abstract: Integral to maintaining wilderness quality is the implementation of ecological, social, and management standards. A substantial body of wilderness research and management experience exists nationwide as a common-pool resource for professionals with a specialized interest in incorporating standards into planning processes. In a 2-day interactive workshop, wilderness managers and researchers joined together to assess the current use of standards, summarize and integrate what has been learned, capitalize on*

the diversity of this work, and develop ideas about directions for the future. The 14 papers in this proceedings represent their collaborative efforts.

The major relevant findings of this workshop are the contributions of experts in the field of wilderness management regarding wilderness standards. This discussion has high applicability to the issue of visitor experience in Glacier Bay as it may be impacted by the presence of cruise ships. **Applicability: High.**

Stankey, G. H., D. W. Lime, et al. (1973). Recreational Carrying Capacity: An Annotated Bibliography, USDA Forest Service**:** 45.

Measuring and Monitoring. Recreational carrying capacity is a major research and management issue in the field of protected areas management. An annotated bibliography including over 200 citations is presented, covering both the ecological and social dimensions of the capacity problem. This document is dated, but provides a good explanation of the concept of carrying capacity, a review of the early literature, and a discussion about visitor preferences for resource quality and human interactions. **Applicability: High.**

Stankey, G. H. (1980). A Comparison of Carrying Capacity Perceptions Among Visitors to Two Wildernesses. Ogden, UT, USDA Forest Service Intermountain Forest and Range Experiment Station**:** 34.

Measuring and Monitoring. This research paper examines how changing use conditions altered visitor preferences for social interaction and management actions. The perception of crowding in two areas with different use levels were compared. Tolerance for high density, perceptions of appropriate behavior, and preferences for alternative management action were evaluated. The authors find that, "*as perceptions shift, people who still seek low-density opportunities will be gradually displaced by those with greater tolerance to higher use.*" This fact may have useful application in addressing the issue of visitor experience in Glacier Bay National Park & Preserve. **Applicability: High.**

Stankey, G. H. and S. F. McCool (1984). "Carrying Capacity in Recreational Settings: Evolution, Appraisal and Application." Leisure Sciences **6**: 453-473.

Measuring and Monitoring. *Abstract: This paper traces the historical evolution of the carrying capacity concept. It argues that many of the fundamental propositions of the concept were understood and articulated early in its evolution. Of particular importance was the recognition that the relationship between visitor satisfaction and use levels was dependent upon the activities in which an individual participated, and needs or desires that activity was to fulfill. The literature reporting generally low*

levels of statistical association between reports of trip satisfaction and levels of encounters is reviewed critically, and a number of mediating influences on this association are suggested. Finally, it is suggested that research focused on defining "How much is too much?" is directed at the wrong issue; rather, the focus should be on the question of what kinds of resource and social conditions are appropriate and acceptable in different settings. A reformulated approach to the carrying-capacity issue - the limits of acceptable change - is introduced and described.

The major relevant finding of this paper is its review of the concept of carrying capacity and the application of limits of acceptable change. Both of these concepts have useful and direct (high) applicability to the visitor experience management issues at Glacier Bay. **Applicability: High.**

Stankey, G. H., D. Cole, et al. (1985). The Limits of Acceptable Change (LAC) System for Wilderness Planning. Gen. Tech. Rep. Ogden, UT, USDA Forest Service, Intermountain Forest and Range Experiment Station**:** 37.

Park Planning and Management. From the Summary*: This paper describes the Limits of Acceptable Change (LAC) system, a framework for establishing acceptable and appropriate resource and social conditions in recreation settings. The LAC has been developed in response to the need of managers for a means of coping with increasing demands on recreational areas in a visible, logical fashion. The LAC also represents a reformulation of the recreational carrying capacity concept, with the primary emphasis now on the conditions desired in the area rather than on how much use an area can tolerate.*

The LAC is not a new idea. It is, however, the latest step in a continuing effort to improve wildland recreation management through definition of more explicit, measurable objectives. Nine steps are involved in the overall process.

Step 1 involves identification of area concerns and issues. In addition to legal guidelines and organizational policy, management of an area needs to reflect area-specific features and values in order that the role of the area at both regional and national levels can be assessed.

In step 2, opportunity classes are defined and described. Opportunity classes represent subunits of the area where different conditions are provided, thereby increasing the diversity of the area. These differences are measured through indicators, identified in step 3, representing resource and social conditions for which management is striving, indicators should be capable of quantitative measurement.

In step 4, the existing condition of the resource and social conditions is inventoried. These data are recorded and mapped, and serve as the basis for the definition. In step 5, of standards for each indicator in each opportunity class. Basing the standard on inventory data helps ensure realism and also clarifies the nature and extent of management activity that will be required to achieve standards.

Step 6 involves identification of alternative allocations of the area among the various opportunity classes. Because different allocations will require different types of management, step 7 requires an analysis of the various costs and benefits of each alternative, in terms of environmental impacts and impacts on visitors as well as administrative costs.

In step 8, the costs and benefits of each alternative are evaluated and a final alternative is selected. This final selection will reflect the responsiveness of the alternative to the issues and concerns identified in step 1 and the management requirements identified in step 7.

Step 9 involves implementation of the selected alternative and establishment of a monitoring program. Monitoring is particularly important as it provides feedback on the effectiveness of the management actions employed, altering managers to the need to consider more rigorous application or the use of other measures.

To demonstrate how these nine steps can lead to an effective management program, a hypothetical case example is described.

This seminal document presents a framework for establishing an effective recreation management program by identifying acceptable and appropriate resource and social conditions in recreation settings. The authors call this framework the limits of acceptable change (LAC) system. The LAC is a reformulation of the recreational carrying capacity concept with focus on desired conditions. The LAC system identifies a nine-step process to follow in developing an effective recreation management program. This general technical report is an often-referenced resource in the field of recreation management and has high applicability to visitor experience management issues in Glacier Bay. **Applicability: High.**

Stankey, G. H. and R. E. Manning (N.D.). Carrying-Capacity of Recreational Settings. A Literature Review, The President's Commission on Americans Outdoors**:** 47-56.

Measuring and Monitoring. From the Research Assessment: *The concept of carrying capacity is large, involving a variety of disciplines. Many studies have been completed, but much of what has been done is descriptive, focused on a single aspect of the problem, and often*

conducted in a hypothetical setting. Much of the research lacks a theoretical base. Overall the utility for management is limited.

Most ecological studies attempt to assess the use-impact relationship after much of the impact has occurred, and with only limited knowledge of the specific amount and type of use that produced it. Few experimental studies or studies of trends have been attempted. Social studies are heavily based on cross-sectional surveys; few behaviorally based studies exist. And like ecological research, few experimental studies or trend studies have been done.

Perhaps the greatest shortcoming in the research on carrying capacity is the lack of holistic, integrative studies that combine natural resource, social, and managerial perspectives. Such studies would produce much more relevant information for decisionmaking needs; findings would also more likely be applied.

The major relevant finding of this paper, authored by experts in the concept of carrying capacity, is the discussion of its application to social factors research. The conclusions regarding crowding and satisfaction have direct (high) applicability to research and management of visitor experience in Glacier Bay. **Applicability: High.**

USDOI-NPS (1989). Glacier Bay National Park and Preserve Wilderness Visitor Use Management Plan.

Park Planning and Management. The purpose of the Wilderness Visitor Use Management Plan is to establish management strategies that minimize the impacts of humans and their technology upon the wilderness resource of Glacier Bay National Park & Preserve, while allowing types and amounts of use appropriate in a wilderness setting. The plan states that "*park management will seek to preserve the natural and aesthetic values that assure the opportunity for solitude, and that permit ecosystems to function without significant human intervention."*

The plan was developed through a public process for the purpose of "*establishing management strategies that minimize the impacts of humans and their technology upon the wilderness resource of Glacier Bay National Park, while allowing types and amounts of use appropriate in a wilderness setting.*" The plan designates wilderness zones, develops wilderness objectives, and presents management prescriptions. This document represents an early management planning effort. It is somewhat dated by the passage of time, changes in visitor demographics, and subsequent advances in management planning processes and practices. It has high applicability in addressing the issue of visitor experience in Glacier Bay National Park & Preserve. **Applicability: High.**

USDOI-NPS (2000). Glacier Bay National Park and Preserve Strategic Plan October 1 2000 - September 30, 2005.

Park Planning and Management: The five year strategic plan was developed through a public planning process. It presents the Glacier Bay National Park and Preserve mission statement and outlines mission goals and long-term goals which address the park's mission.

The Glacier Bay National Park and Preserve mission statement is as follows: *It is the mission of the National Park Service to achieve, maintain and communicate Glacier Bay National Park and Preserve's status as a superlative Park, Biosphere Reserve and World Heritage site. NPS will manage use to provide a unique, inspirational visitor experience while protecting the areas's marine, glacial and terrestrial ecosystems. NPS will recognize and perpetuate park values, including those associated with the Tlingit homeland, wilderness, and solitude.*

The plan follows a standard National Park Service format. It is limited in scope to long term goals, so by design lacks specificity and detail in addressing issues of visitor experience. However, it has high applicability to Glacier Bay and high value as background and guidance on the issue of visitor experience. **Applicability: High.**

USDOI-NPS (2003). Glacier Bay National Park and Preserve Vessel Quotas and Operating Requirements Volumes I and II Final Environmental Impact Statement.

Park Planning and Management: This EIS, developed through a public planning process, describes a range of alternative vessel quotas and operating requirements, existing conditions, and environmental consequences of the alternatives. Most pertinent to the issue of social impact of cruise ships is Table 3-12 Glacier Bay Visitor Traffic, 1997-2002 and Chapter 4.4.2 Visitor Experience which describes the potential effects of implementing the proposed alternatives on visitor experience.

Impacts identified from the presence of large cruise ships include diminishment of the experience of other visitors due to visual effects (loss of natural vistas) and loss of wilderness experience; the intrusion of vessel noise on visitor solitude; and the potential for vessels to scare wildlife, thus impacting visitor wildlife viewing opportunities. Also noted was the impact from cruise ship PA systems, which can be heard for several miles.

The EIS has direct applicability and high value to the issue of visitor experience in Glacier Bay. **Applicability: High.**

USFS (1982). ROS Users Guide**:** 38.

> **Park Planning and Management.** *"The Recreational Opportunity Spectrum provides a framework for stratifying and defining classes of outdoor recreation opportunity environments."* Recreation opportunity is *"the availability of a real choice for a user to participate in a preferred activity within a preferred setting, in order to realize those satisfying experiences which are desired."* This user's guide explains how to develop a Recreational Opportunity Spectrum (ROS) ranging from primitive through motorized and roaded to urban settings. The ROS uses physical, social, and managerial settings to develop recreational capacity and management prescriptions.
>
> The ROS process is a mainstay in the public land management toolkit. However, ROS may not allow enough detailed focus on visitor experience to provide guidance in the issue of cruise ship compatibility in Glacier Bay National Park & Preserve. **Applicability: Moderate.**

Washburne, R. F. (1982). "Wilderness Recreational Carrying Capacity: Are Numbers Necessary?" Journal of Forestry: 726-728.

> **Measuring and Monitoring.** *Abstract: In most wildernesses, where there is currently no need to reduce amounts of use, setting numerical carrying capacities is not helpful. Such capacities are intended to be indicators of overuse; when use reaches capacity, wilderness values are in imminent danger. However, amount of use is only one factor weakly related to wilderness conditions. In most situations, setting standards and monitoring specific conditions would be more effective than calculating use capacities. Such monitoring would seem to meet requirements of the National Forest Management Act pertaining to wilderness management.*
>
> The major relevant findings of this article are the preference for setting standards and monitoring specific conditions rather than the use of carrying capacity as a measurement of satisfactory wilderness conditions. This approach to carrying capacity might have some application to Glacier Bay National Park & Preserve. Standards for visitor wilderness experience could be established and monitored. **Applicability: High.**

Watson, A. and M. J. Niccolucci (1995). Conflicting Goals of Wilderness Management: Natural Conditions vs. Natural Experiences. Gen. Tech. Report, USDA Forest Service.

> **Measuring and Monitoring.** *Abstract: Beliefs and attitudes underlying wilderness visitors' support for use restrictions were studied. Some evidence shows that in overused places visitors cite both protection of the resource and the wilderness experience as reasons for supporting*

restrictions. The research reported here provides the opportunity to assess the relative contribution of each of theses reasons, and others, to visitor support for use restrictions at three wildernesses in Oregon. Support for reducing the total amount of use was best predicted by crowding measures for day visitors and by a combination of crowding and physical environment impact (dominated by physical impacts) for overnight users. This knowledge has implications for other situations involving conflicting demands on natural resources.

From the Article: Support for use limitation systems that reduce recreational access appears to be dependent upon a combination of visitor perceptions that the area has too many people and that visitor impacts have reached unacceptable levels.

Application of this point to the visitor experience in Glacier Bay may be limited when the issue revolves around individual visitors vs. cruise ships rather than among individual visitors. **Applicability: High.**

Whittaker, D. and B. Shelby (1988). "Types of Norms for Recreation Impacts: Extending the Social Norms Concept." Journal of Leisure Research **20**(40): 271-273.

Measuring and Monitoring. *Abstract: Evaluative information about appropriate use conditions is a necessary component of managing impacts in recreation settings. Social norm theory, which suggests there may be group agreement about appropriate conditions, can be applied to help establish standards. Information was collected regarding boaters' standards for a variety of social and ecological impacts on the Deschutes River in Oregon. Results suggest norms can be identified and appear to conform to three different types. A "no tolerance" norm exists when most users agree that any level of impact is unacceptable, a "single tolerance" norm exists when users show similar agreement at impact levels greater than zero, and a "multiple tolerance" norm exists when two or more groups of users have different standards for acceptable impact levels. These norm types help in understanding differences in acceptable impact levels and group agreement. Implications are discussed for establishing management standards from normative information.*

The major relevant finding of this article is the development of norms for management standards. This work could have useful application in addressing visitor experience in Glacier Bay National Park & Preserve as it pertains to impacts from cruise ships. **Applicability: High.**